Yearbook of Astronomy 1969

Editor **PATRICK MOORE**

SIDGWICK & JACKSON

1969 Yearbook of Astronomy

Edited by
PATRICK MOORE

Sidgwick & Jackson
London

First published 1968
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1 *Tavistock Chambers, Bloomsbury Way*
*London, WC*1

SBN.283.98039.7

Printed in Great Britain
by Thomas Nelson (Printers) Ltd
London and Edinburgh

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Editorial

With the 1969 *Yearbook* we have a new publisher, and the Editor wishes to express his sincere thanks to Mr J. S. Knapp-Fisher, of Messrs Sidgwick and Jackson, for invaluable help and encouragement.

As before, Dr J. G. Porter has been responsible for the whole of Part I except for additional comments to the monthly notes; without him it would be virtually impossible to produce the *Yearbook*. The articles by D. A. Allen, V. A. Firsoff and H. G. Miles cover a wide range of topics; and as a new departure the 'observers' section' has been extended to give two introductory articles, by T. J. C. A. Moseley and Henry Brinton, as well as another of James Muirden's 'cycles' and the usual lists of interesting objects. To all these contributors, I can only express my thanks. I am also grateful to Lawrence Clarke for contributing line drawings.

PATRICK MOORE

Preface

New readers will find that all the information in this *Yearbook* is given in diagrammatic or descriptive form; the positions of the planets may easily be found on the specially designed star charts, while the monthly notes describe the movements of the planets, and give details of other astronomical phenomena that may be observed from these latitudes. The reader who needs more detailed information will find *Norton's Star Atlas* (Gall and Inglis, 21*s*) invaluable, while more precise positions of the planets and their satellites, together with predictions of occultations, meteor showers and periodic comets may be found in the *Handbook* of the British Astronomical Association. A somewhat similar publication is the *Observer's Handbook* of the Royal Astronomical Society of Canada, and readers will also find details of forthcoming events given in the British quarterly periodical *Planetarium* and in the American *Sky and Telescope* which also publishes complete details of all occultations visible in North America.

Important Note

The star charts are drawn, and the notes are, in general, designed for use in latitude 52 degrees north, but may be used without alteration throughout the British Isles, and (except in the case of eclipses and occultations) in other countries of similar north latitude.

The times given on the star charts and in the Monthly Notes are generally given as local times, using the 24-hour clock, the day beginning at midnight. Ignoring small differences of longitude, this local time may be taken as Greenwich Mean Time (G.M.T.) in the British Isles, or as the appropriate Standard Time in other Time Zones. If Summer Time is in use, the clocks will have been

advanced by one hour, and this hour must be subtracted from the clock time to give local time.

Readers in Great Britain should note that permanent Summer Time is now in force. Although this is called 'British Standard Time' it is not, in fact, a true astronomical Standard Time, and *one hour should be deducted from B.S.T. to give G.M.T.* The times of a few events are given in G.M.T., but this is clearly stated in all such cases.

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PART ONE

Events of 1969

Monthly Charts and Astronomical Phenomena

Notes on the Star Charts

The stars, together with the Sun, Moon and planets, seem to be set on the surface of the celestial sphere, which appears to rotate about the Earth from east to west. Since it is impossible to represent a curved surface accurately on a plane, any kind of star map is bound to contain some form of distortion. But it is well known that the eye can endure some kinds of distortion better than others, and it is particularly true that the eye is most sensitive to deviations from the vertical and horizontal. For this reason the star charts given in this volume on pages 18 to 41 have been designed to give a true representation of vertical and horizontal lines, whatever may be the resulting distortion in the shape of a constellation figure. It will be found that the amount of distortion is, in general, quite small, and is only obvious in the case of large constellations such as Leo and Pegasus, when these appear at the top of the charts, and so are drawn out sideways.

The charts show all stars down to the fourth magnitude, together with a number of fainter stars which are necessary to define the shape of a constellation. There is no standard system for representing the outlines of the constellations, and triangles and other simple figures have been used to give outlines which are easy to follow with the naked eye. The names of the constellations are given, together with the proper names of the brighter stars. The apparent magnitudes of the stars are indicated roughly by using four different sizes of dots, the larger dots representing the bright stars.

There are four such charts at each opening, and these give a complete coverage of the sky up to an altitude of 62½ degrees; there are twelve such sets to cover the entire year. The upper two charts show the southern sky, south being at the centre; the coverage is 200 degrees in azimuth, from a little north of east

(top left) to a little north of west (top right). The two lower charts show the northern sky, from a little south of west (lower left) to a little south of east (lower right). There is thus an overlap east and west.

The charts have been drawn for a latitude of 52 degrees, but may be taken without appreciable error to apply to all parts of the British Isles. They will also be equally suitable for any other part of the world having a north latitude of about 52 degrees – e.g. parts of Europe and Asia, and Canada. In such cases the times given must be taken as local time, and not G.M.T., which applies only to the British Isles.

Because the sidereal day is shorter than the solar day, the stars appear to rise and set about four minutes earlier each day, which amounts to two hours in a month. Hence the twelve sets of charts are sufficient to give the appearance of the sky throughout the day at intervals of two hours, or at the same time of night at monthly intervals throughout the year. The actual range of dates and times when the stars on the charts are visible is indicated at the top of each page. This information is summarized in the following table, which gives the number of the star chart to be used for any given month and time.

G.M.T.	16^h	18^h	20^h	22^h	0^h	2^h	4^h	6^h
January	10	11	12	1	2	3	4	5
February		12	1	2	3	4	5	6
March			2	3	4	5	6	
April			3	4	5	6		
May			4	5	6	7		
June			5	6	7			
July			6	7	8	9		
August			7	8	9	10	11	
September		7	8	9	10	11	12	
October		8	9	10	11	12	1	
November	8	9	10	11	12	1	2	3
December	9	10	11	12	1	2	3	4

The charts are drawn to scale, and estimates of altitude and azimuth may be made from them. These values will necessarily be mere approximations, since no observer will be exactly on the meridian of Greenwich at 52 degrees latitude, but they will generally serve for the identification of stars and planets. The horizontal measurements, marked at every ten degrees, give the azimuths (or true bearings) measured from the north round through east (90 degrees), south (180 degrees), and west (270 degrees). The vertical measurements, similarly marked, give the altitudes of the stars up to $62\frac{1}{2}$ degrees.

The ecliptic is drawn as a broken line on which the longitude is marked at every ten degrees; the positions of the planets at any time are then easily found by reference to the table immediately following the star charts on page 44.

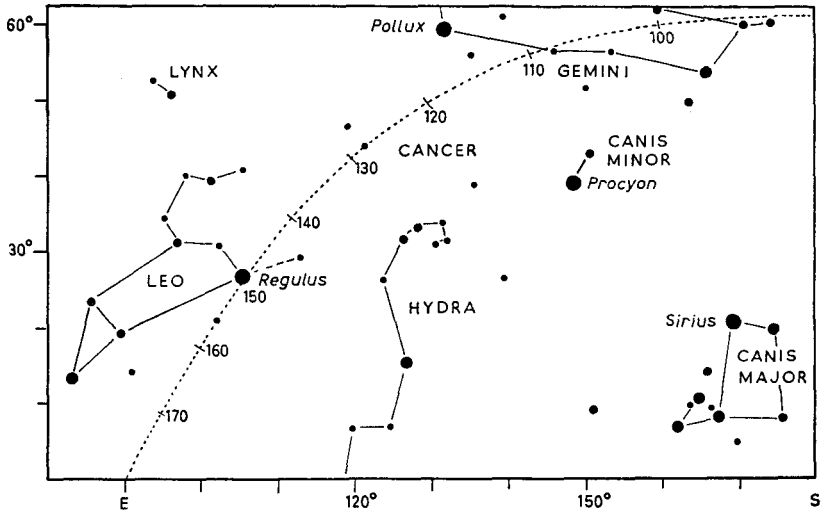
There is a curious illusion that stars at an altitude of 60 degrees or more are actually overhead, and the beginner may often feel that he is leaning over backwards in trying to see them. These high-altitude stars, being nearer the pole, move more slowly across the sky, and a different kind of map may therefore be used. These overhead stars are given separately on pages 42 and 43, the entire year being covered at one opening. Each of the four maps shows the overhead stars at times which correspond to those of three of the main star charts. The position of the zenith in latitude 52 degrees is indicated by a cross, and this cross also marks the centre of a circle which is 35 degrees from the zenith, and which therefore indicates an altitude of 55 degrees; there is thus a small overlap with the main charts.

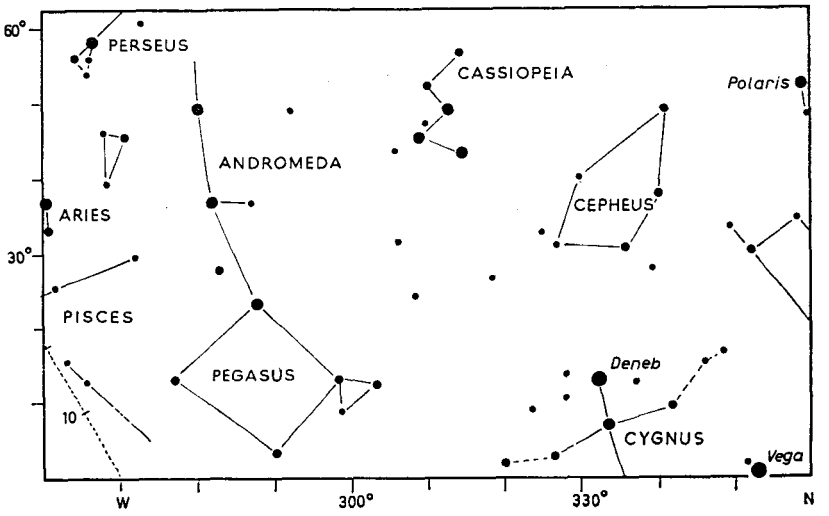
The broken line leading from north to south is numbered to indicate the corresponding main chart. Thus on page 42 the N-S line numbered 6 is to be regarded as an extension of the S line of chart 6 on pages 28 and 29, and at the top of these pages are given dates and times which are appropriate.

The scale is the same on all the charts (approximately 25 degrees to the inch), but the overhead stars are plotted as a true map on a conical projection, and are not simple graphs like the main charts.

1L

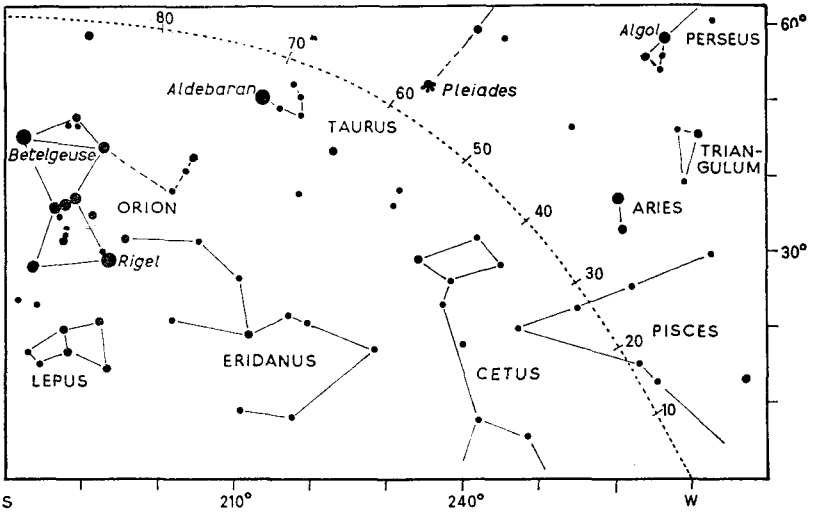
October 6 at 5h	October 21 at 4h
November 6 at 3h	November 21 at 2h
December 6 at 1h	December 21 at midnight
January 6 at 23h	January 21 at 22h
February 6 at 21h	February 21 at 20h

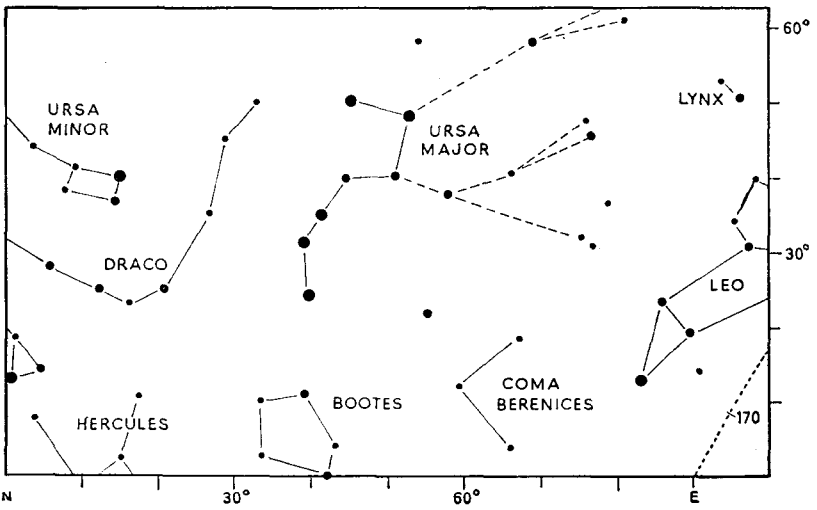




October 6 at	5h	October 21 at	4h
November 6 at	3h	November 21 at	2h
December 6 at	1h	December 21 at	midnight
January 6 at	23h	January 21 at	22h
February 6 at	21h	February 21 at	20h

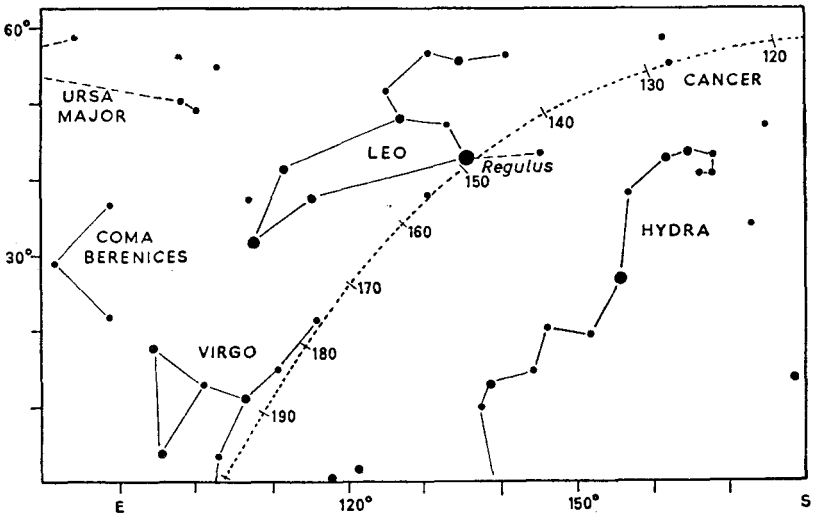
1R

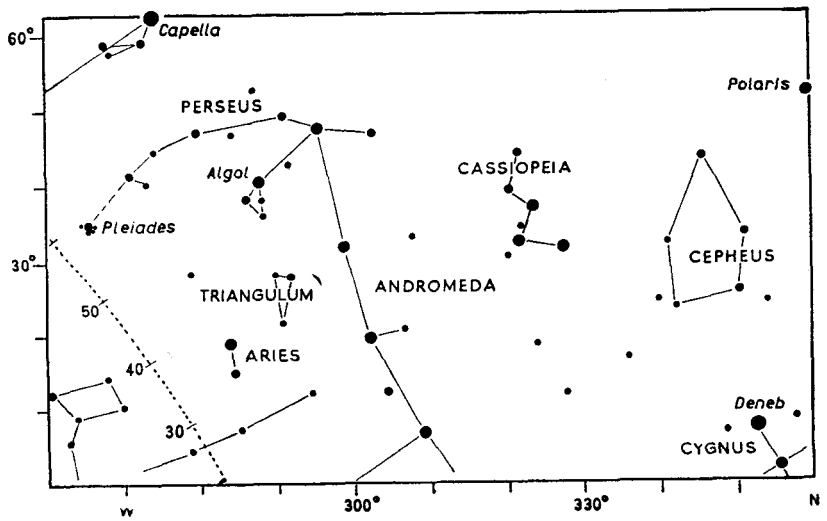




2L

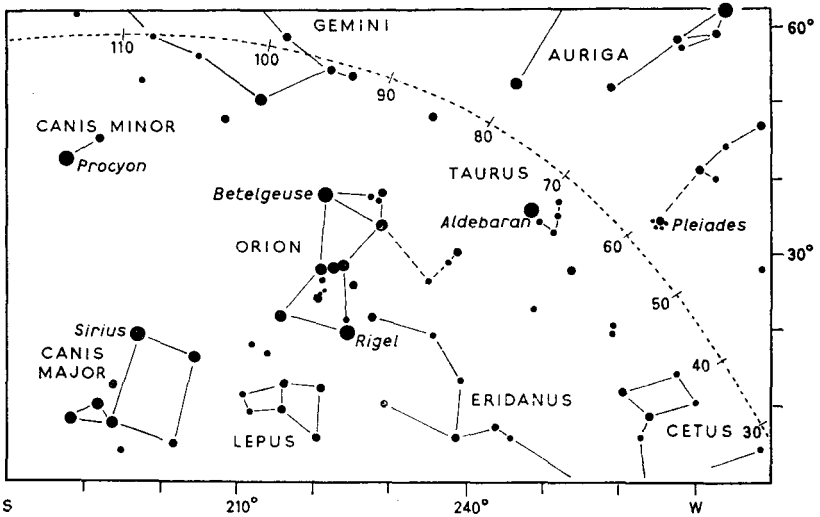
November 6 at	5h	November 21 at	4h
December 6 at	3h	December 21 at	2h
January 6 at	1h	January 21 at	midnight
February 6 at	23h	February 21 at	22h
March 6 at	21h	March 21 at	20h

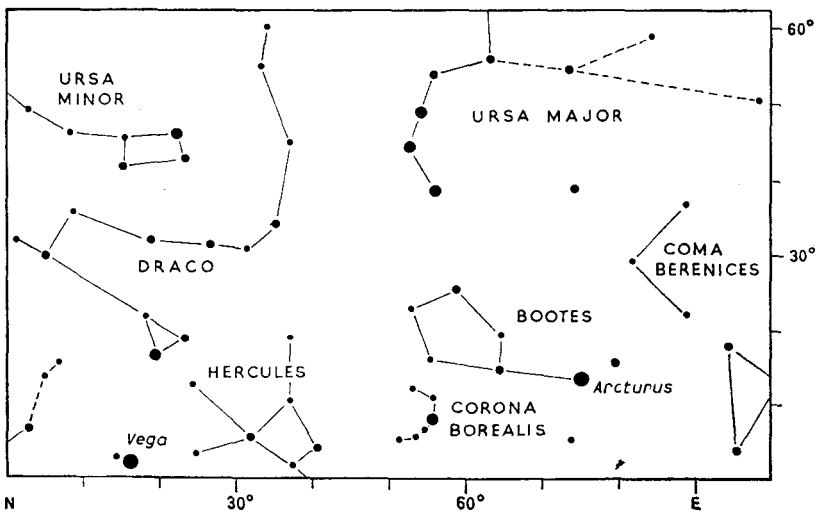




November 6 at	5h	November 21 at	4h
December 6 at	3h	December 21 at	2h
January 6 at	1h	January 21 at	midnight
February 6 at	23h	February 21 at	22h
March 6 at	21h	March 21 at	20h

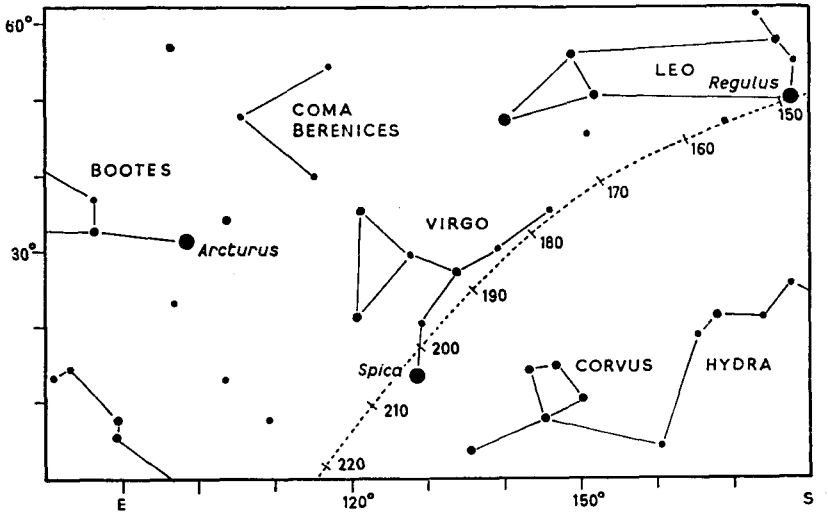
2R

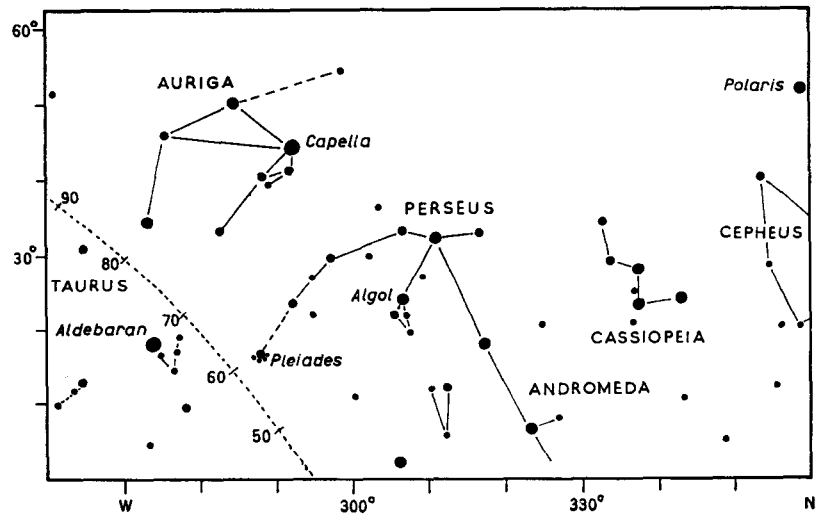




3L

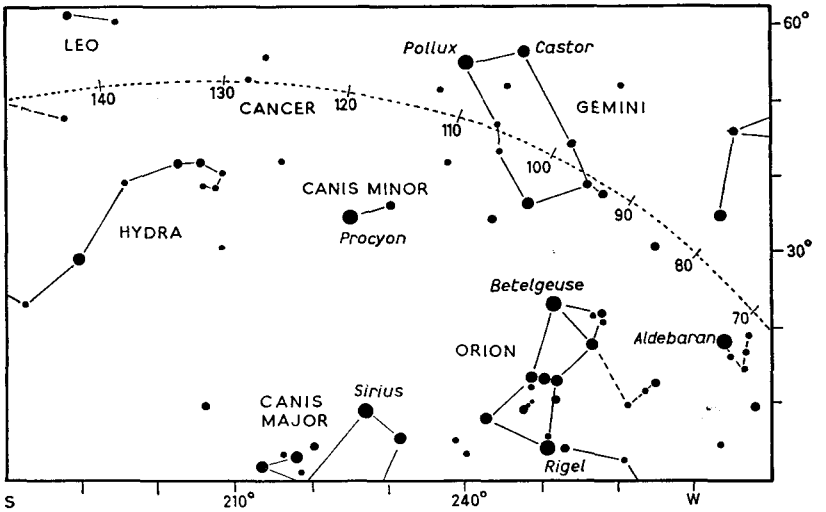
December 6 at	5^h	December 21 at	4^h
January 6 at	3^h	January 21 at	2^h
February 6 at	1^h	February 21 at	midnight
March 6 at	23^h	March 21 at	22^h
April 6 at	21^h	April 21 at	20^h

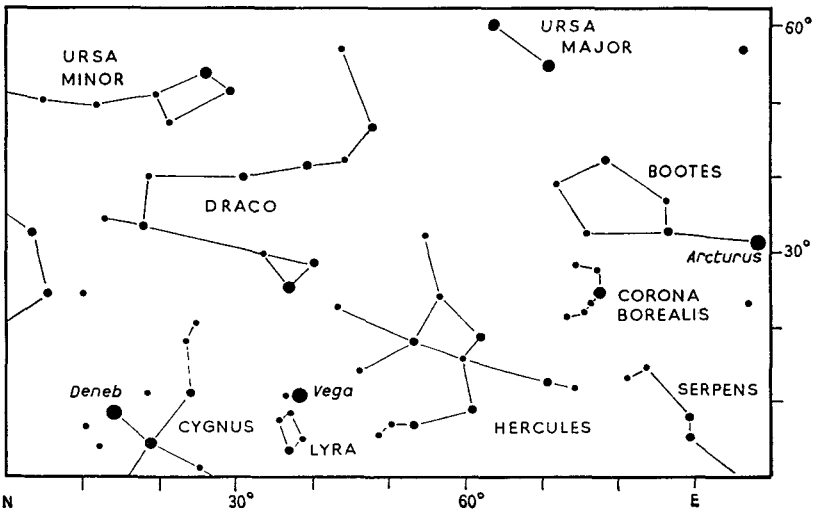




December 6 at	5^h	December 21 at	4^h
January 6 at	3^h	January 21 at	2^h
February 6 at	1^h	February 21 at	midnight
March 6 at	23^h	March 21 at	22^h
April 6 at	21^h	April 21 at	20^h

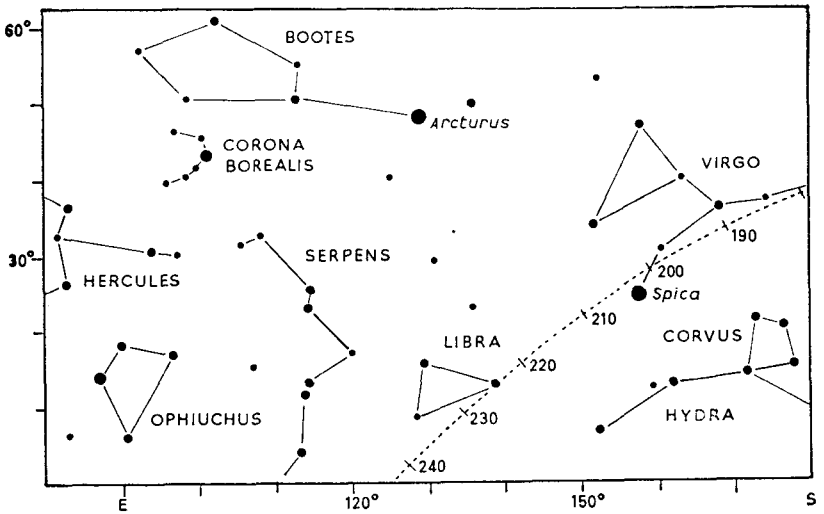
3R

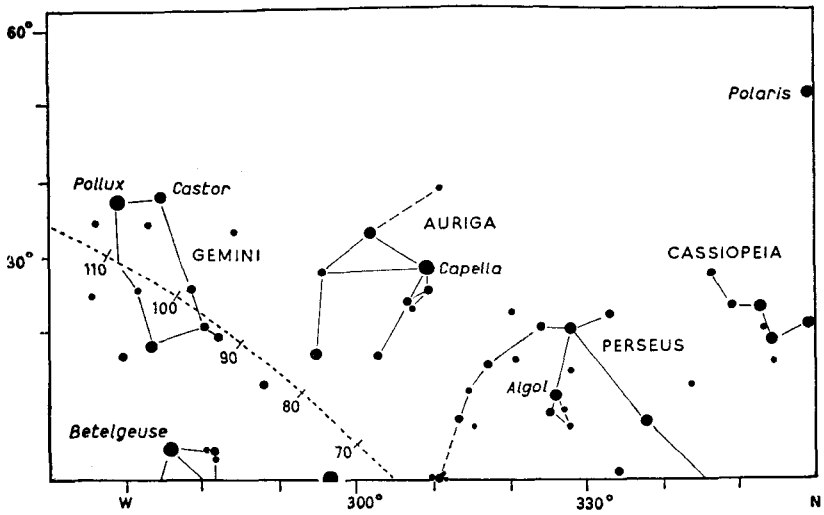




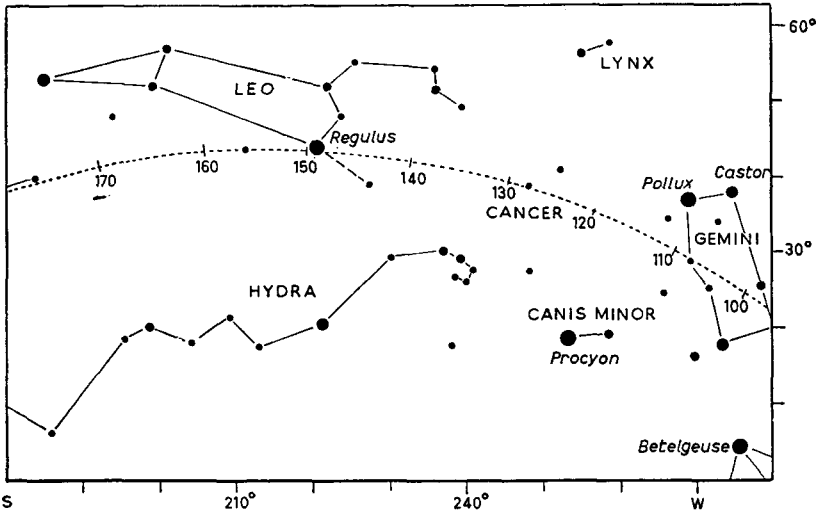
4L

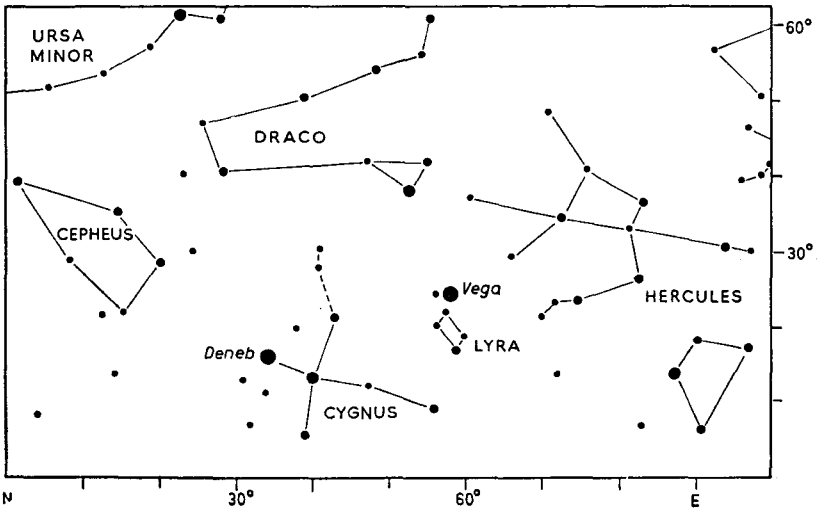
January 6 at 5h	January 21 at 4h
February 6 at 3h	February 21 at 2h
March 6 at 1h	March 21 at midnight
April 6 at 23h	April 21 at 22h
May 6 at 21h	May 21 at 20h





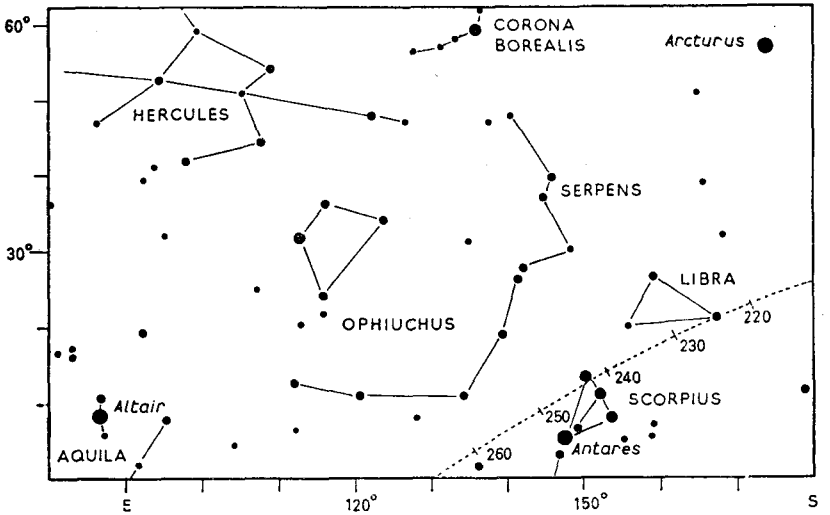
January 6 at 5h	January 21 at 4h	**4R**
February 6 at 3h	February 21 at 2h	
March 6 at 1h	March 21 at midnight	
April 6 at 23h	April 21 at 22h	
May 6 at 21h	May 21 at 20h	

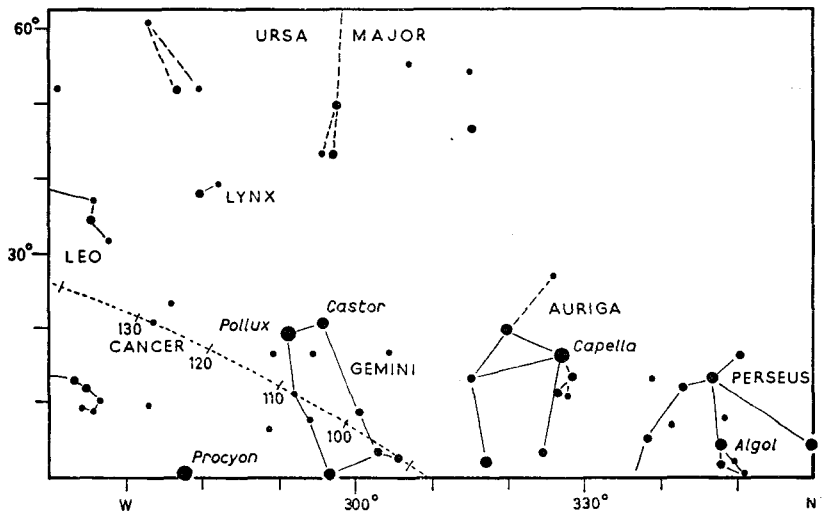




5L

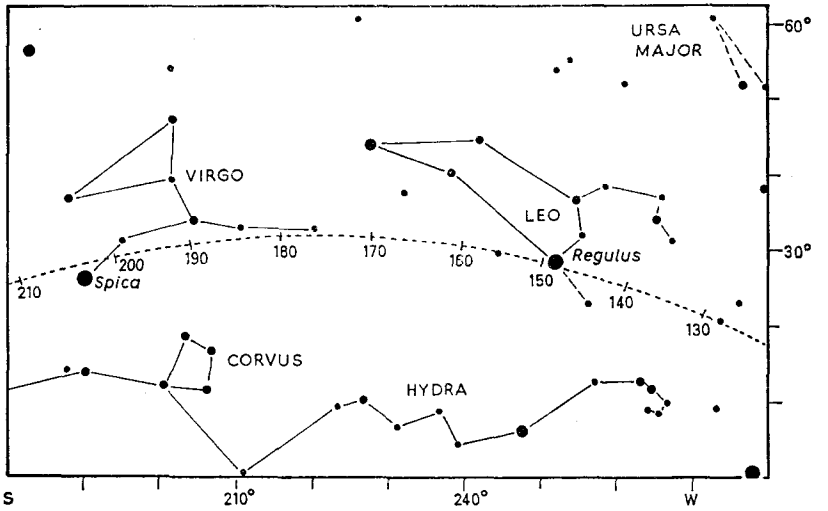
January 6 at 7h	January 21 at 6h
February 6 at 5h	February 21 at 4h
March 6 at 3h	March 21 at 2h
April 6 at 1h	April 21 at midnight
May 6 at 23h	May 21 at 22h

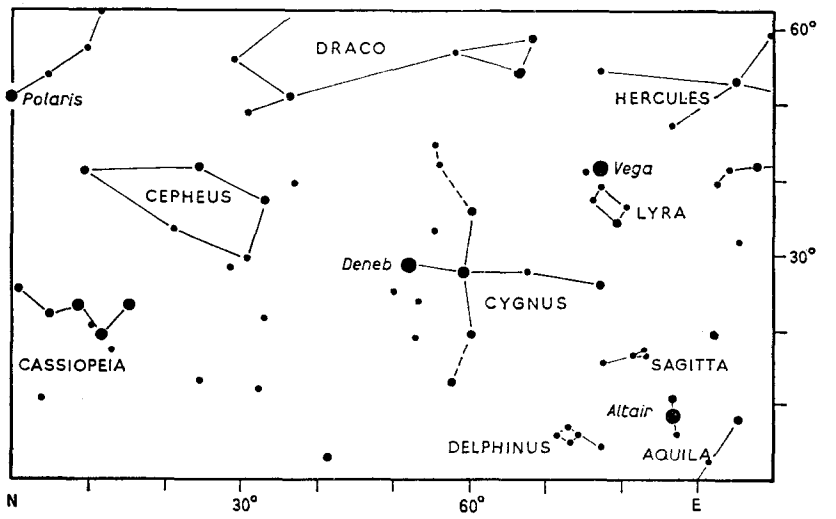




January 6 at	7^h	January 21 at	6^h
February 6 at	5^h	February 21 at	4^h
March 6 at	3^h	March 21 at	2^h
April 6 at	1^h	April 21 at	midnight
May 6 at	23^h	May 21 at	22^h

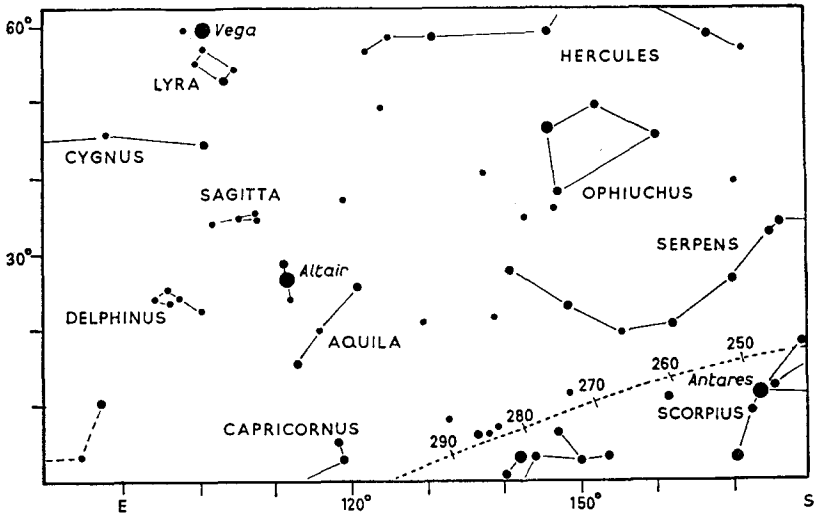
5R

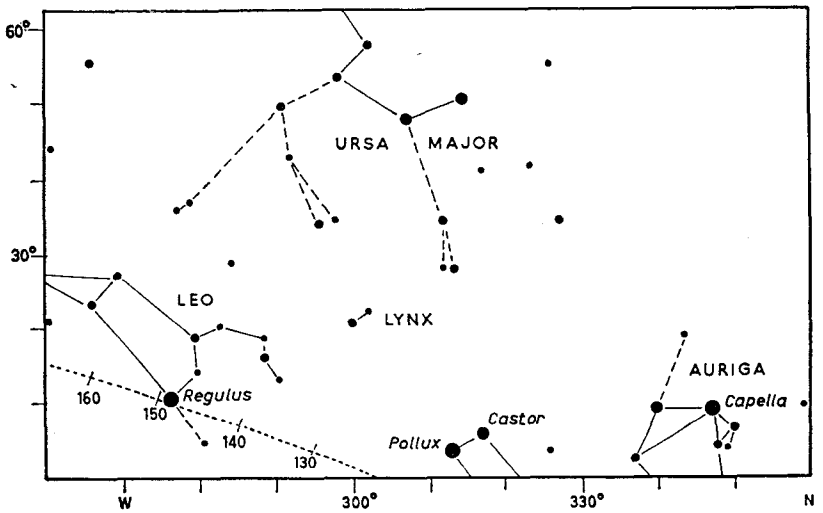




6L

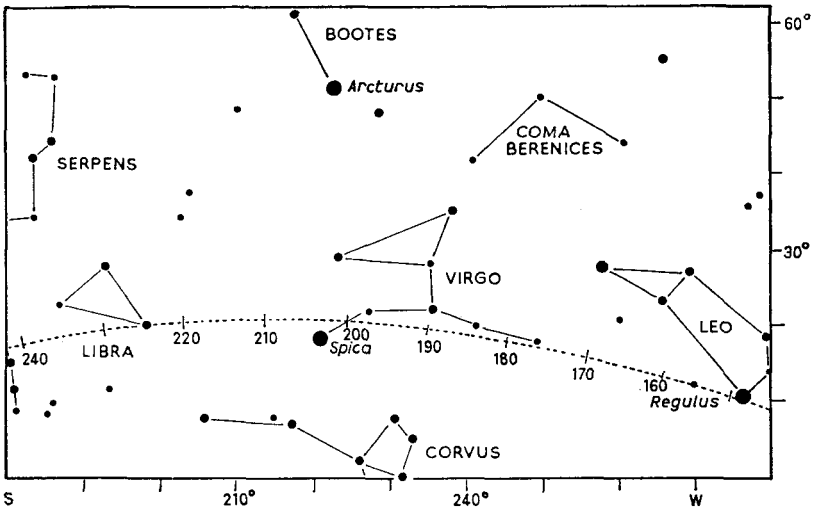
March 6 at 5h	March 21 at 4h
April 6 at 3h	April 21 at 2h
May 6 at 1h	May 21 at midnight
June 6 at 23h	June 21 at 22h
July 6 at 21h	July 21 at 20h

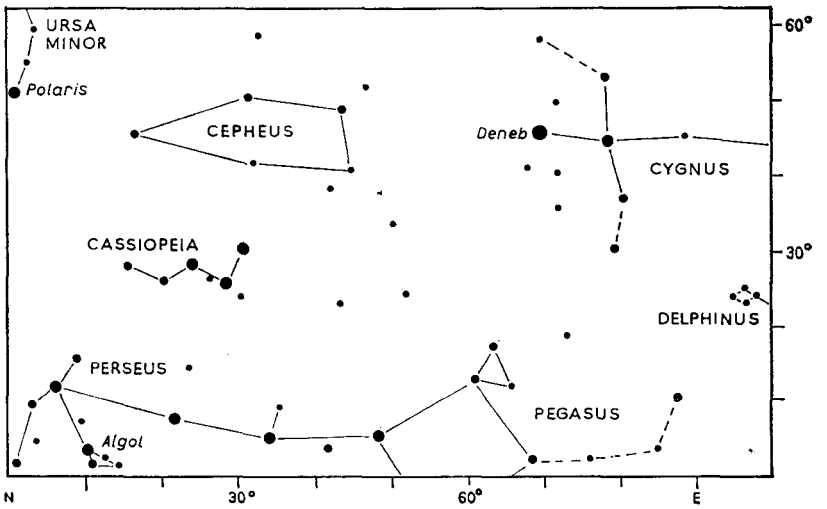




March 6 at	5h	March 21 at	4h
April 6 at	3h	April 21 at	2h
May 6 at	1h	May 21 at	midnight
June 6 at	23h	June 21 at	22h
July 6 at	21h	July 21 at	20h

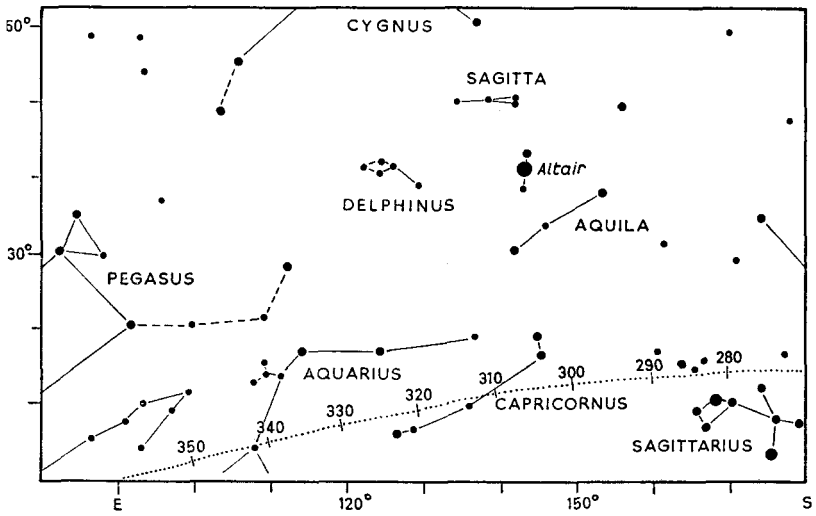
6R

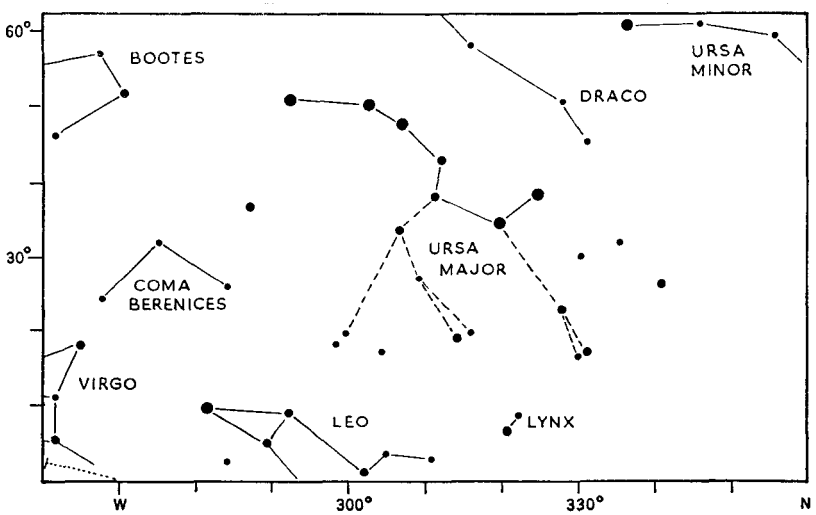




7L

May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h

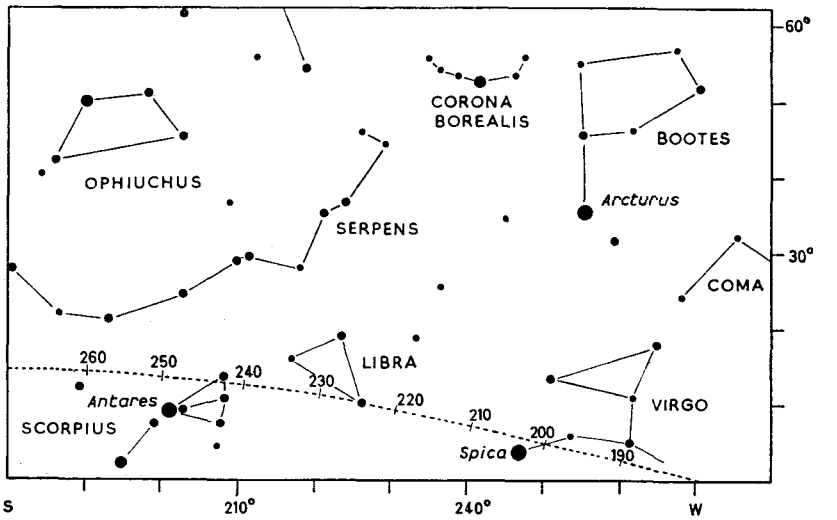


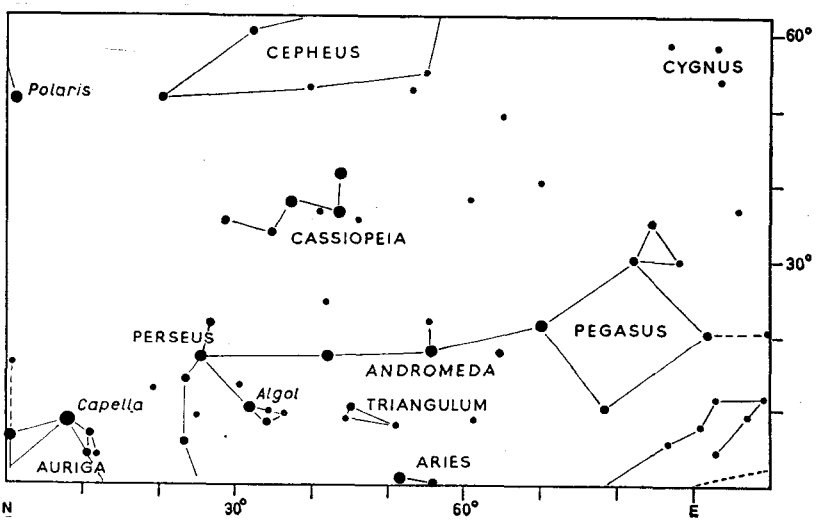


May 6 at 3h
June 6 at 1h
July 6 at 23h
August 6 at 21h
September 6 at 19h

May 21 at 2h
June 21 at midnight
July 21 at 22h
August 21 at 20h
September 21 at 18h

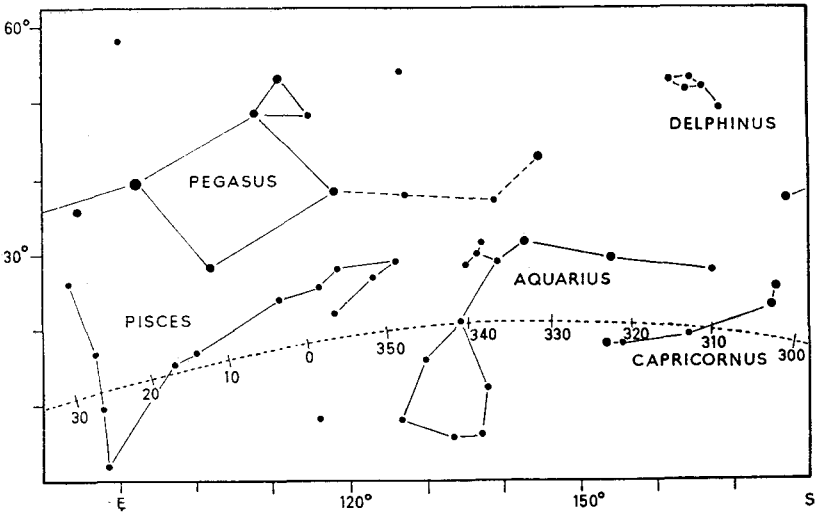
7R

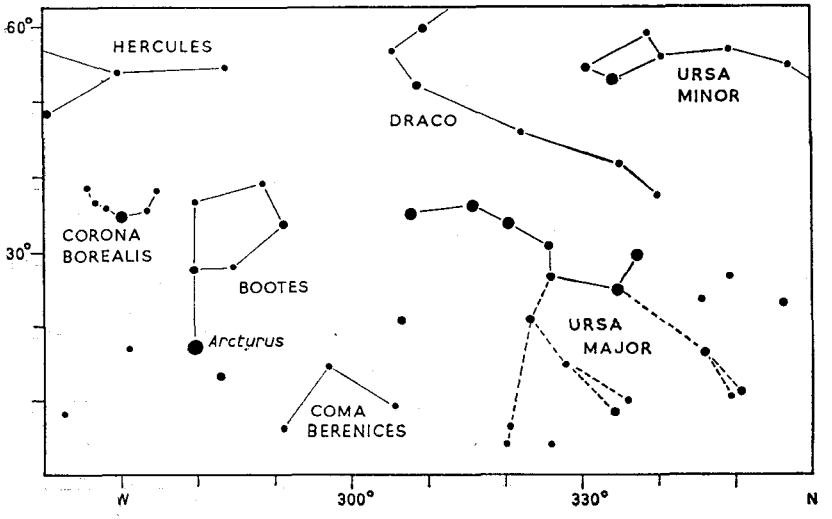




8L

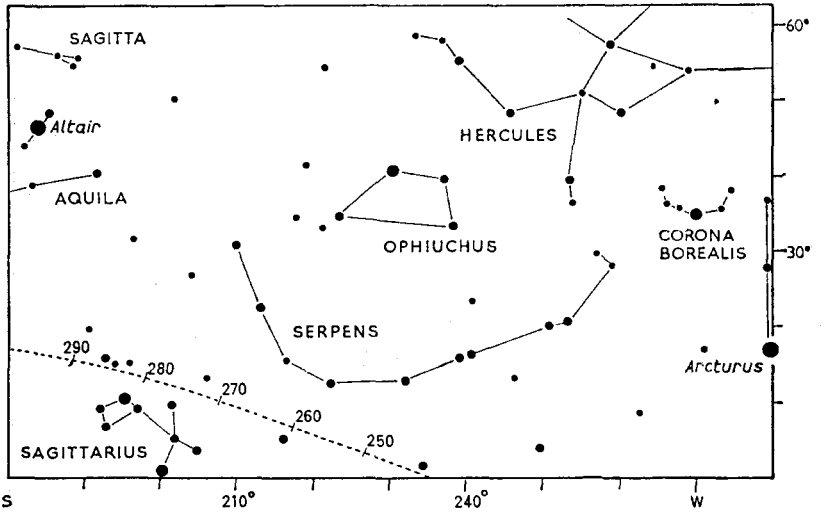
July 6 at 1h	July 21 at midnight
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h

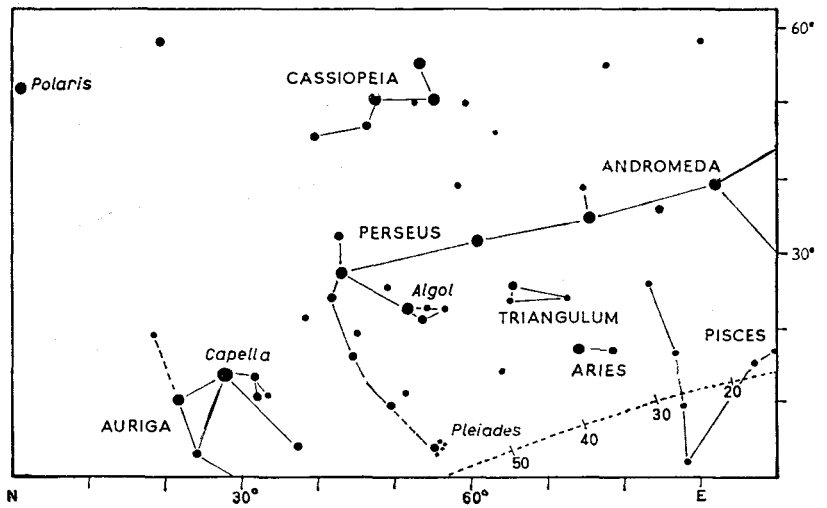




July 6 at 1h	July 21 at midnight
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h

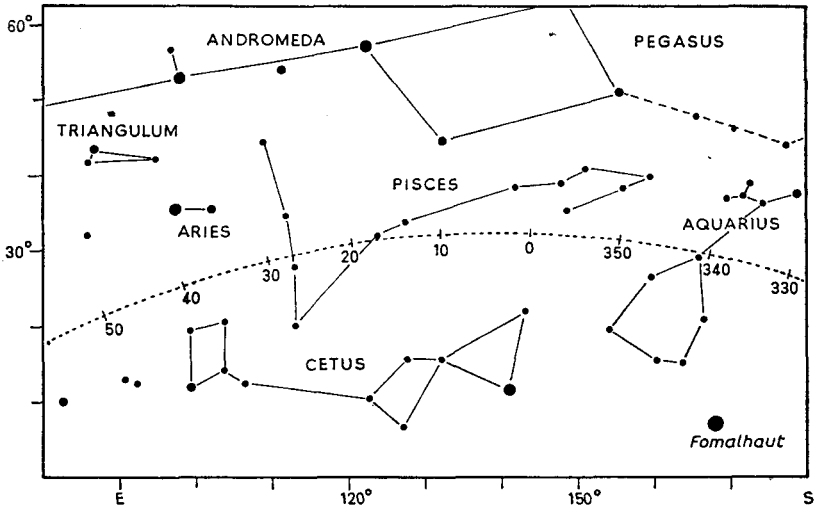
8R

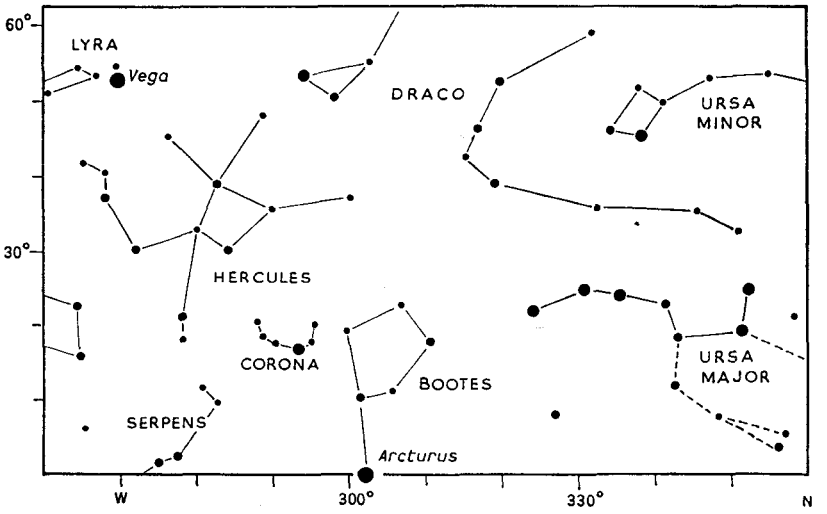




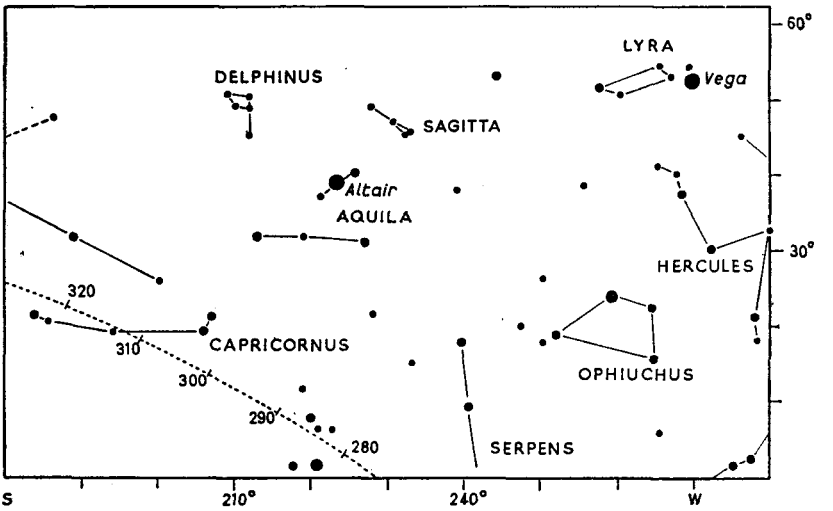
9L

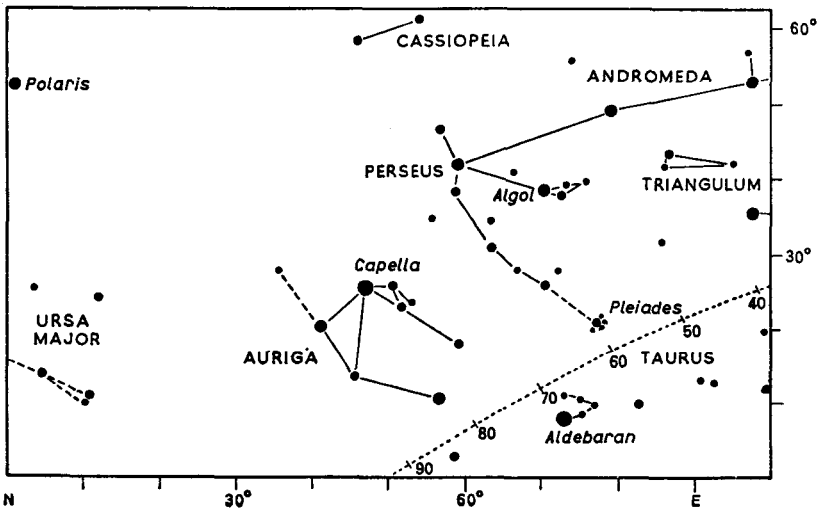
August 6 at 1h	August 21 at midnight
September 6 at 23h	September 21 at 22h
October 6 at 21h	October 21 at 20h
November 6 at 19h	November 21 at 18h
December 6 at 17h	December 21 at 16h





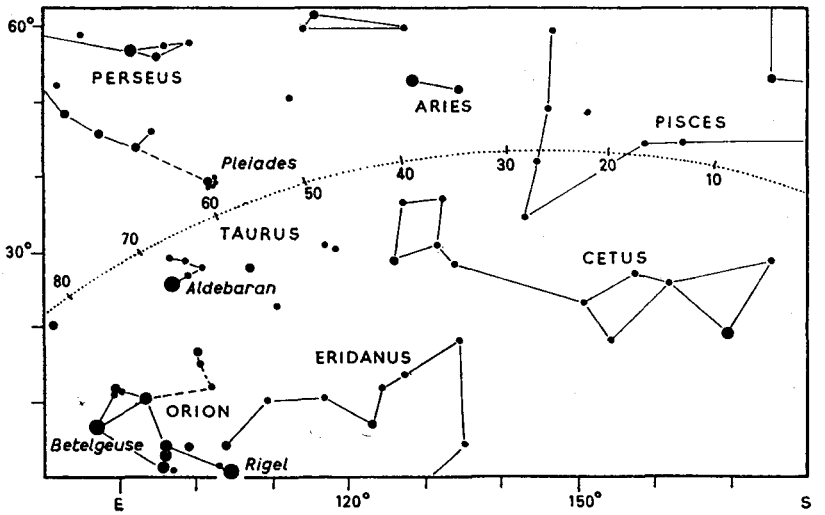
August 6 at 1h	August 21 at midnight	**9R**
September 6 at 23h	September 21 at 22h	
October 6 at 21h	October 21 at 20h	
November 6 at 19h	November 21 at 18h	
December 6 at 17h	December 21 at 16h	

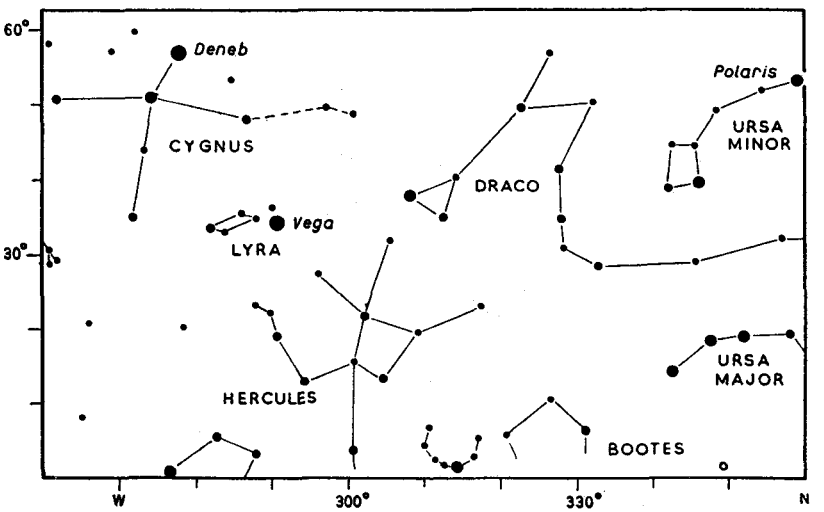




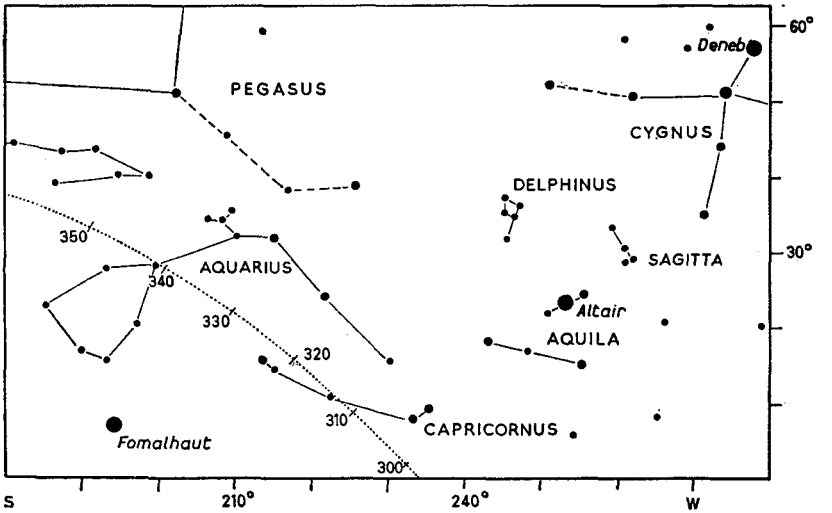
10L

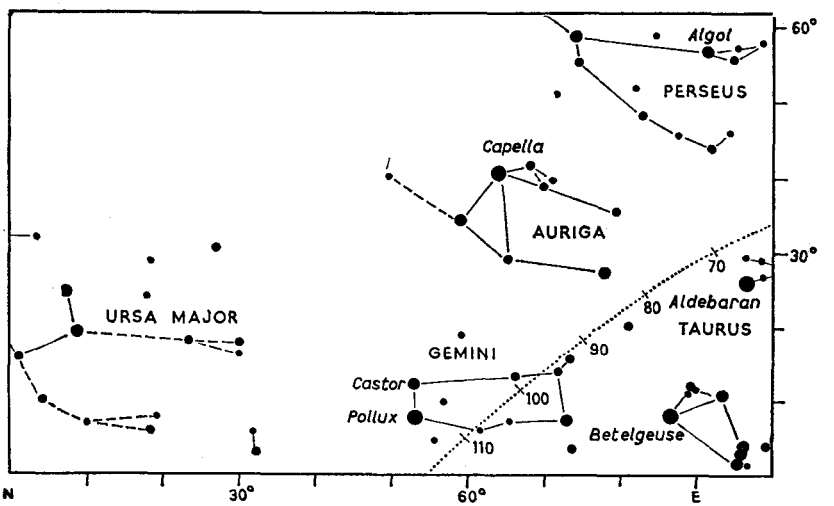
August 6 at 3h	August 21 at 2h
September 6 at 1h	September 21 at midnight
October 6 at 23h	October 21 at 22h
November 6 at 21h	November 21 at 20h
December 6 at 19h	December 21 at 18h





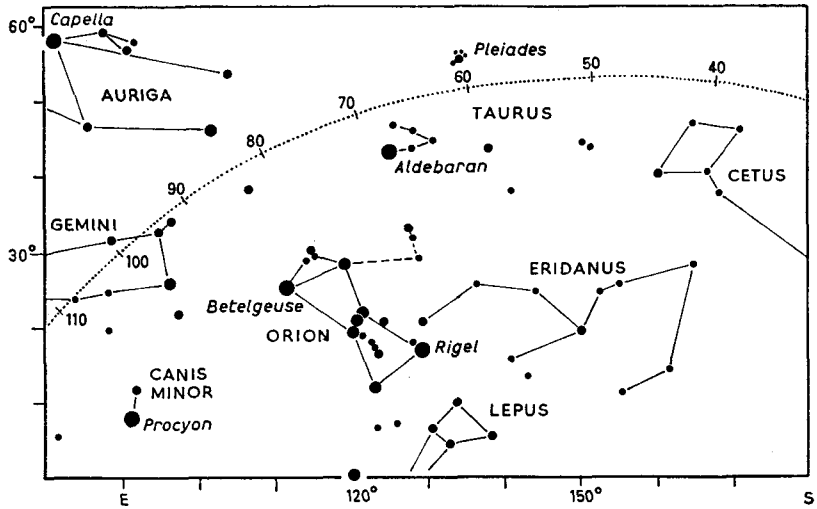
August 6 at 3h	August 21 at 2h	**10R**
September 6 at 1h	September 21 at midnight	
October 6 at 23h	October 21 at 22h	
November 6 at 21h	November 21 at 20h	
December 6 at 19h	December 21 at 18h	

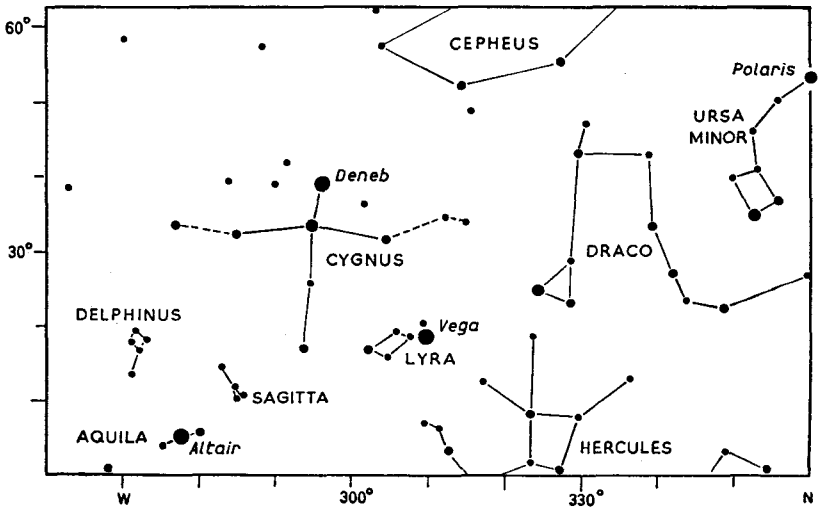




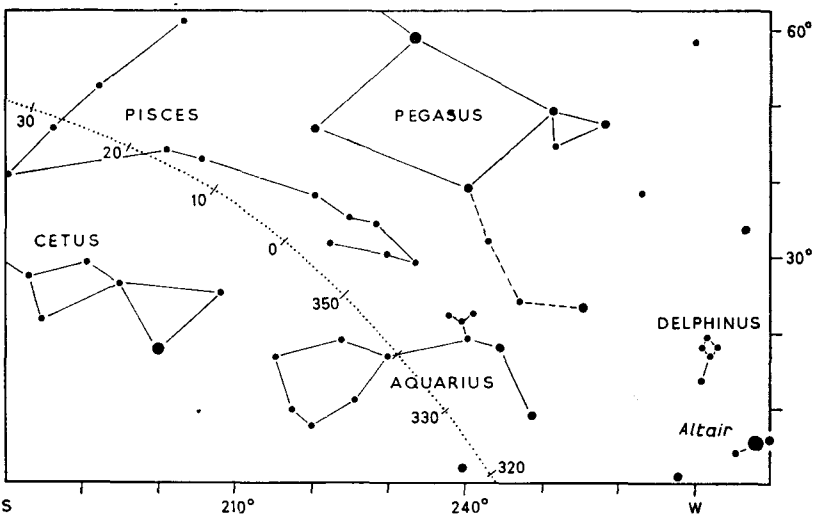
11L

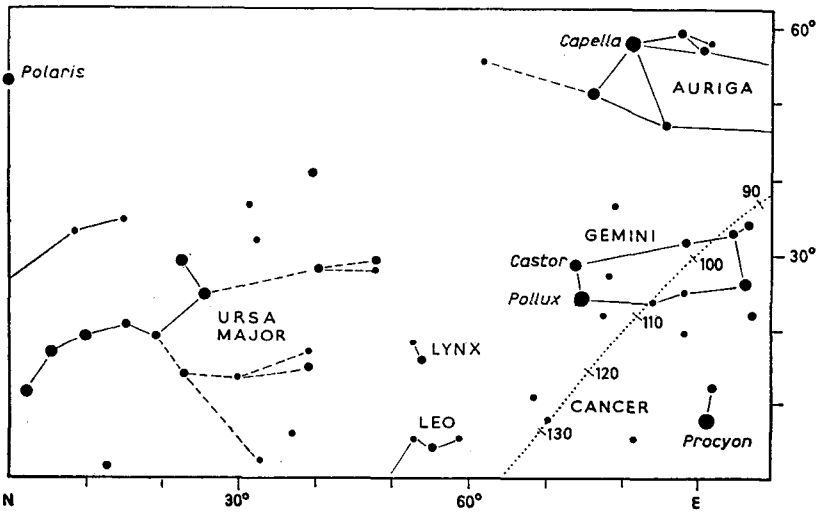
September 6 at 3h	September 21 at 2h
October 6 at 1h	October 21 at midnight
November 6 at 23h	November 21 at 22h
December 6 at 21h	December 21 at 20h
January 6 at 19h	January 21 at 18h





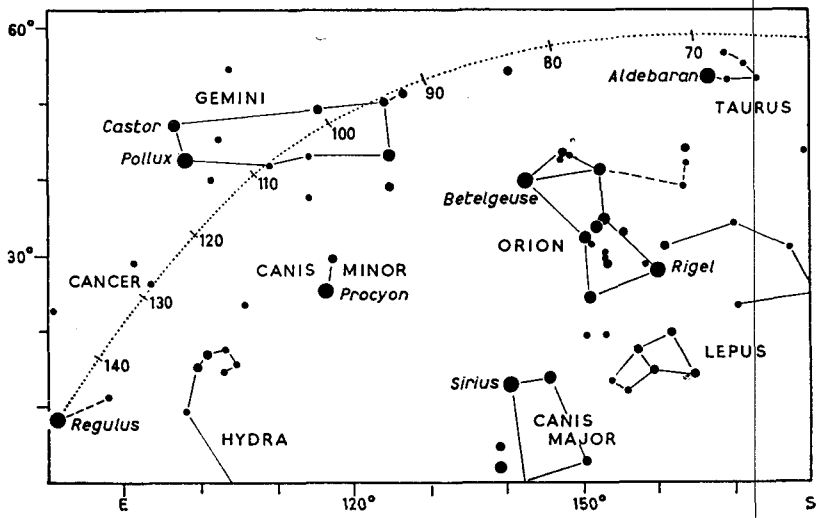
September 6 at 3h	September 21 at 2h	**11R**
October 6 at 1h	October 21 at midnight	
November 6 at 23h	November 21 at 22h	
December 6 at 21h	December 21 at 20h	
January 6 at 19h	January 21 at 18h	

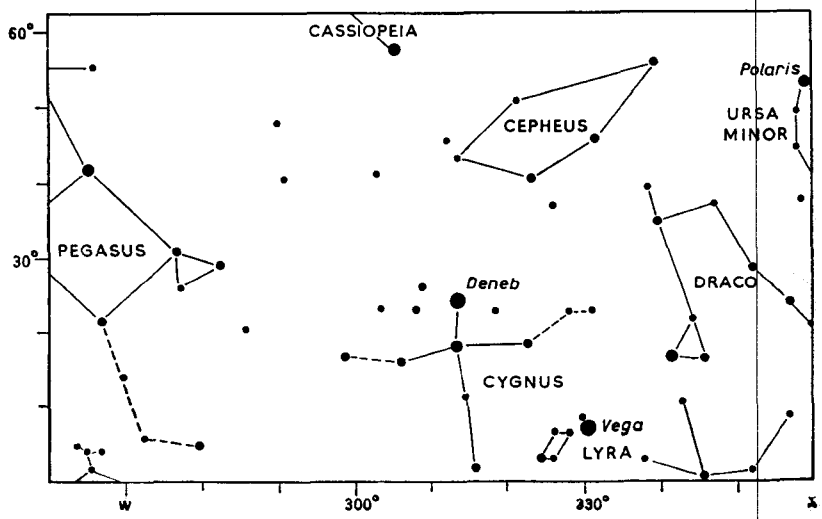




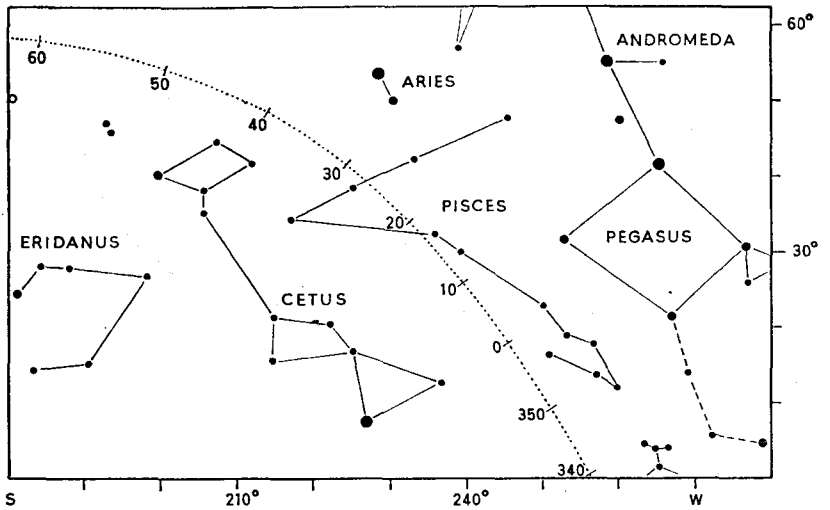
12L

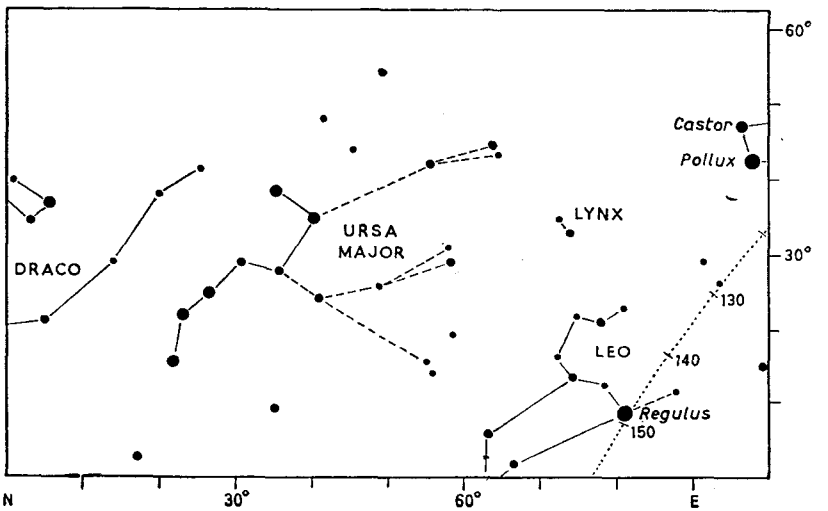
October 6 at 3h	October 21 at 2h
November 6 at 1h	November 21 at midnight
December 6 at 23h	December 21 at 22h
January 6 at 21h	January 21 at 20h
February 6 at 19h	February 21 at 18h

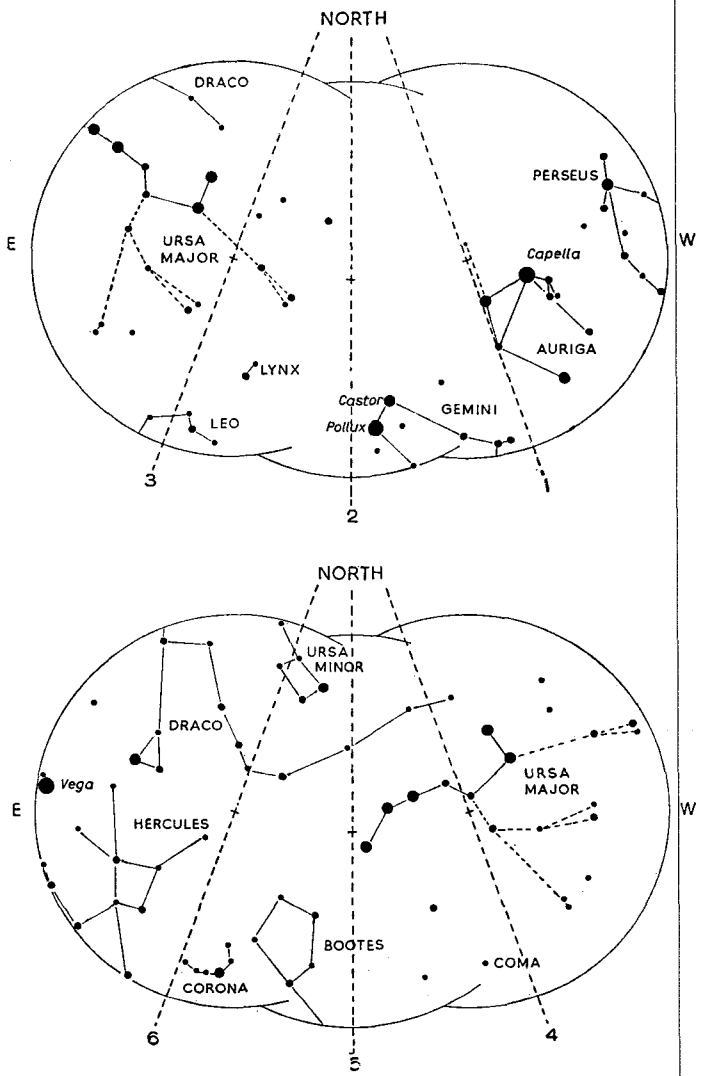




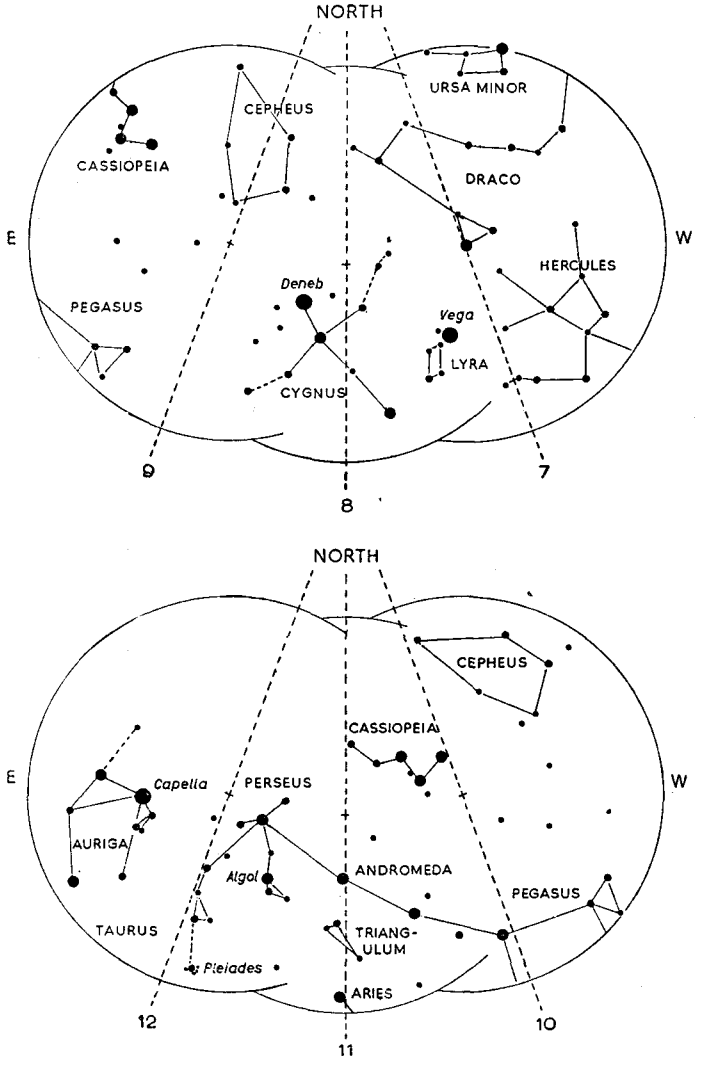
October 6 at 3h	October 21 at 2h	**12R**
November 6 at 1h	November 21 at midnight	
December 6 at 23h	December 21 at 22h	
January 6 at 21h	January 21 at 20h	
February 6 at 19h	February 21 at 18h	







Overhead stars



Overhead stars

The Planets in 1969

DATE		*Venus*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
January	6	332°	215°	186°	20°	184°	238°
	21	348	223	187	21	184	239
February	6	3	231	186	22	184	239
	21	15	238	185	23	184	239
March	6	22	244	184	24	183	239
	21	24	250	182	26	182	239
April	6	17	254	180	28	182	239
	21	10	257	178	30	181	238
May	6	11	256	177	32	181	238
	21	18	253	177	33	180	238
June	6	31	248	177	35	180	237
	21	45	243	178	37	180	237
July	6	60	241	179	38	181	237
	21	75	242	181	39	181	236
August	6	93	246	184	40	182	236
	21	110	253	187	40	182	236
September	6	129	261	190	40	183	237
	21	148	270	193	39	184	237
October	6	166	280	196	38	185	237
	21	185	290	199	37	186	238
November	6	205	301	203	36	187	238
	21	223	312	206	35	188	239
December	6	242	323	209	34	188	239
	21	261	334	211	33	189	240
Conjunction:							
Inferior		Apr. 8					
Superior		—	—	Oct. 9	Apr. 18	Sept. 27	Nov. 20
Opposition:		—	May 31	Mar. 21	Oct. 29	Mar. 22	May 18

Mercury moves so quickly among the stars that it is not possible to indicate its position on the star charts at a convenient interval. The monthly notes must be consulted for the best times at which the planet may be seen.

The positions of the other planets are given in the table on the opposite page. This gives the apparent longitudes on dates which correspond to those of the star charts, and the position of the planet may at once be found near the ecliptic at the given longitude.

Examples:

(1) *What is the bright planet seen rising in the east below the figure of Leo at about* 23^h *on February* 8*?*

Star chart 2L is appropriate, and it is then seen that this planet must have a longitude of about 180°–190°. The table opposite shows both Jupiter and Uranus in this position, but since Uranus is barely visible to the naked eye, the bright planet must be Jupiter.

(2) *Where may Mars be found on a night in mid-August?*

From the table on the opposite page the longitude of Mars at this time is about 250° and star charts 6 and 7 will show the appearance of the sky at this time. Mars will then be some degrees north of *Antares*, low in the south at 20^h and setting in the south-west before midnight.

The Planets and the Ecliptic

The paths of the planets about the Sun all lie close to the plane of the ecliptic, which is marked for us in the sky by the apparent path of the Sun among the stars, and is shown on the star charts by a broken line. The Moon and planets will always be found close to this line, never departing from it by more than about 7 degrees. Thus the planets are most favourably placed for observation when the ecliptic is well displayed, and this means that it should be as high in the sky as possible. This avoids the difficulty of finding a clear horizon, and also overcomes the problem of atmospheric absorption, which greatly reduces the light of the stars. Thus a star at an altitude of 10 degrees suffers a loss of 60 per cent of its light, which corresponds to a whole magnitude; at an altitude of only 4 degrees, the loss may amount to two magnitudes.

The position of the ecliptic in the sky is therefore of great importance, and since it is tilted at about 23½ degrees to the equator, it is only at certain times of the day or year that it is displayed to the best advantage. It will be realized that the Sun (and therefore the ecliptic) is at its highest in the sky at noon in midsummer, and at its lowest at noon in midwinter. Allowing for the daily motion of the sky, these times lead to the fact that the ecliptic is highest at midnight in winter, at sunset in the spring, at noon in summer and at sunrise in the autumn. Hence these are the best times to see the planets. Thus, if Venus is an evening star, in the western sky after sunset, it will be seen to best advantage if this occurs in the spring, when the ecliptic is high in the sky and slopes down steeply to the north-west. This means that the planet is not only higher in the sky, but will remain for a much longer period above the horizon. For similar reasons, a morning star will be seen at its best on autumn mornings before sunrise, when the ecliptic is high in the east. The outer planets, which can come to opposition and are then in the south at midnight, are best seen when opposition occurs in the winter months. Clearly the summer is the least favourable time to observe the planets, for the ecliptic is always low in the sky on summer nights.

Notes on the Planets in the monthly diagrams

The following general notes on observing the planets are followed by detailed month-by-month accounts of the behaviour of the planets, and of other interesting phenomena. These monthly notes include diagrams of the apparent movements of the planets at favourable times of the year. Additional notes on other astronomical phenomena will be found on the following pages.

The inferior planets, Mercury and Venus, move in smaller orbits than that of the Earth, and so are always seen near the Sun. They are most obvious at the times of greatest angular distance from the Sun (greatest elongation), which may reach 28 degrees for Mercury, or 47 degrees for Venus. They are then seen as evening stars in the western sky after sunset (at eastern elongations) or as morning stars in the eastern sky before sunrise (at western elongations). The succession of phenomena, conjunctions and elongations, always follows the same order, but the intervals between them are not equal. Thus if either planet is moving round the far side of its orbit its motion will be to the east, in the same direction in which the Sun appears to be moving. It therefore takes much longer for the planet to overtake the Sun – that is, to come to superior conjunction – than it does when moving round to inferior conjunction, between Sun and Earth. The intervals given in the following table are average values; they remain fairly constant in the case of Venus, which travels in an almost circular orbit. In the case of Mercury, however, conditions vary widely because of the great eccentricity and inclination of the planet's orbit.

		Mercury	*Venus*
Inferior conj.	to Elongation West	22 days	72 days
Elongation West	to Superior conj.	36 days	220 days
Superior conj.	to Elongation East	36 days	220 days
Elongation East	to Inferior conj.	22 days	72 days

The greatest brilliancy of Venus always occurs about a month *before* greatest western elongation (as a morning star), or a month *after* greatest eastern elongation (as an evening star). No such rule can be given for Mercury, because its distance from Sun and Earth can vary over a wide range.

Mercury is not likely to be seen unless a clear horizon is available; it is seldom seen as much as 10 degrees above the horizon in the twilight sky. In general it may be said that the most favourable times for seeing Mercury as an evening star will be in spring, some days before greatest eastern elongation; in autumn it may be seen as a morning star some days after greatest western elongation.

Venus is the brightest of the planets, and may be seen on occasions in broad daylight. Like Mercury, it is alternately a morning and an evening star, and will be highest in the sky when it is a morning star in autumn, or an evening star in spring. Venus is seen to best advantage when it comes to greatest eastern elongation in June; it is then well north of the Sun in the spring months and is a brilliant object in the sunset sky over a long period.

The superior planets, which travel in orbits larger than that of the Earth, differ from Mercury and Venus in that they can be seen opposite the Sun in the sky. The superior planets are morning stars after conjunction with the Sun, rising earlier each day until they come to opposition. They will then be in the south at midnight, and visible all night. After opposition, they are evening stars, setting earlier each evening until they set in the west with the Sun at the next conjunction. The interval between conjunctions or between oppositions is greatest for Mars (over two years). At the time of opposition, the planet is nearest the Earth, and therefore at its brightest. This change in brightness is most noticeable with Mars, whose distance from the Earth can vary considerably; the other superior planets are at such great distances that there is very little change in brightness from one opposition to another. The effect of altitude is, however, of importance, for at a December opposition the planet will be among the stars of Taurus or Gemini, and can then be at an altitude of more than 60 degrees in southern England. At a summer opposition, when the planet is in

Sagittarius, it may only rise to about 15 degrees above the southern horizon, and so make a less impressive appearance.

Mars, whose orbit is appreciably eccentric, comes nearest to the Earth at an opposition at the end of August; it may then be brighter even than Jupiter, but rather low in the sky in Aquarius. These favourable oppositions occur every fifteen or seventeen years (1924, 1941, 1956, 1973), but in this country the planet is probably better seen at an opposition in the autumn or winter, when it is higher in the sky. Oppositions of Mars occur at an average interval of 780 days, and during this time the planet makes a complete circuit of the sky.

Jupiter is always a bright planet, and comes to opposition a month later each year, having moved, roughly speaking, from one Zodiacal constellation to the next.

Saturn moves much more slowly than Jupiter, and may remain in the same constellation for several years. The brightness of Saturn depends on the aspect of its rings, as well as on the distance from Earth and Sun. The rings are now opening, and the planet is growing brighter at each opposition.

Uranus, *Neptune* and *Pluto* are hardly likely to attract the attention of observers without adequate instruments, but some notes on their present positions in the sky will be found in the March and May notes.

Phases of the moon, 1969

New Moon			*First Quarter*			*Full Moon*			*Last Quarter*		
d	h	m	d	h	m	d	h	m	d	h	m
						Jan. 3	18	28	Jan. 11	14	00
Jan. 18	04	59	Jan. 25	08	23	Feb. 2	12	56	Feb. 10	00	08
Feb. 16	16	25	Feb. 24	04	30	Mar. 4	05	17	Mar. 11	07	44
Mar. 18	04	51	Mar. 26	00	48	Apr. 2	18	45	Apr. 9	13	58
Apr. 16	18	16	Apr. 24	19	45	May 2	05	13	May 8	20	12
May 16	08	26	May 24	12	15	May 31	13	18	June 7	03	39
June 14	23	09	June 23	01	44	June 29	20	04	July 6	13	17
July 14	14	11	July 22	12	10	July 29	02	45	Aug. 5	01	38
Aug. 13	05	17	Aug. 20	20	03	Aug. 27	10	32	Sept. 3	16	58
Sept. 11	19	56	Sept. 19	02	25	Sept. 25	20	21	Oct. 3	11	05
Oct. 11	09	39	Oct. 18	08	32	Oct. 25	08	44	Nov. 2	07	14
Nov. 9	22	11	Nov. 16	15	45	Nov. 23	23	54	Dec. 2	03	50
Dec. 9	09	42	Dec. 16	01	09	Dec. 23	17	35	Dec. 31	22	52

All times are G.M.T.

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MONTHLY NOTES, 1969

January

Full Moon: January 3 *New Moon:* January 18

Earth is at perihelion (nearest to the Sun) on January 3, at a distance of 91,400,000 miles.

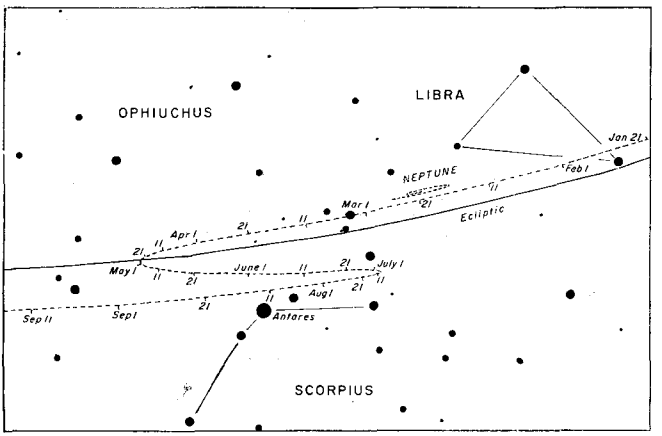
Mercury is at greatest eastern elongation (evening star) on January 13 (19 degrees); it is then north of the Sun, and it may be possible to catch a glimpse of the planet a few degrees above the horizon in the south-west about half an hour after sunset. Inferior conjunction occurs on January 29.

Venus has been moving slowly out from superior conjunction since last June, and comes to greatest eastern elongation as an evening star on January 26 (47 degrees). It is a brilliant object (magnitude −3·8 to −4·1) and may be seen against a dark sky, setting about four hours after the Sun. Venus will be seen close to the crescent Moon on the evening of January 21, when the planet will be occulted for observers in the southern hemisphere.

Mars is a morning star, moving direct from Virgo into Libra; it will be seen just north of Alpha Libræ (*Zuben el Genubi*) towards the end of the month. Mars rises in the early morning hours (about 2^h at the beginning of the month) but is not yet a very bright object (magnitude +1·5 to +1·1); the only comparable star in this neighbourhood is *Spica* (magnitude +1·2) some distance away to the west.

Jupiter is a bright morning star (magnitude −1·6 to −1·8), rising in the east at midnight at the beginning of the year. It will be seen in the western part of Virgo and reaches a stationary point on January 21. At the end of the month it will be moving in the retrograde direction as it approaches opposition in March.

Saturn is an evening star, setting in the west at midnight in mid-January, and will be seen in the south at sunset at the end of the month. Saturn is moving direct among the faint stars of Pisces, and



Mars, January to September 1969

it is much brighter (magnitude +0·8) than any other object in the neighbourhood.

Occultations of Planets, and by Planets. Occultations of stars by the Moon are common, and timing them is of importance; the positions of the stars in the sky are much better determined than the movements of the Moon, so that an occultation timing can be used to fix the position of the Moon at that moment.

Occultations of planets are not so valuable, but they are of course very spectacular. The disappearance is not instantaneous, as with a star; it takes some time for the whole of the planet's disk to be covered. This will happen on January 21 this year, when Venus will go behind the Moon. Unfortunately the occultation will not be visible from the northern hemisphere.

Occasionally a planet may occult a star. If the planet has an atmosphere, as with Venus, the star flickers and fades for some

moments before disappearing, and observations of this kind have been used to measure the extent of Venus' refracting atmosphere. On July 7, 1959, Venus occulted the bright star Regulus, and though the phenomenon took place in broad daylight it was observable with moderate telescopes; many measures were made, with useful results. However, it will be many years before Venus again occults a bright star.

Mutual occultations of planets have been observed, but of course are extremely rare, and none are due in the near future.

The Varied Zodiac. This month Saturn is still to be seen in the constellation of Pisces (the Fishes), in the general region of the Square of Pegasus. It is much brighter than any star in its neighbourhood, and in fact there are no brilliant stars in Pisces; the group is an obscure one, and is not easy to pick out unless the watcher has a fair knowledge of the constellations.

When the Zodiac was divided up into twelve signs, all were regarded as of equal importance, but the Zodiacal constellations themselves are very unequal in brilliance. Aries, the Ram, consists of one fairly bright star (Hamal) and two more which make up a reasonably conspicuous little group. Taurus, the Bull, is one of the major constellations, and contains many interesting objects; in addition to the red first-magnitude star Aldebaran, it has the two famous star-clusters of the Hyades and the Pleiades, to say nothing of the remarkable Crab Nebula and the eclipsing variable Lambda Tauri. The second brightest star in the constellation, Al Nath, is not far below the first magnitude; it lies in the direction of Auriga, and was formerly known as Gamma Aurigæ instead of its modern designation of Beta Tauri.

Gemini, the Twins, is also extremely bright and rich. Pollux is of the first magnitude, Castor only just below, Alhena also well above magnitude 2; the Milky Way runs through Gemini, and there are many interesting objects of all kinds. On the other hand the next group, Cancer or the Crab, is very dim and ghostly, and distinguished only because it contains the fine open star-cluster Præsepe.

Leo, the Lion, has the celebrated pattern of stars making up the Sickle; Regulus is of the first magnitude, while Algieba in the Sickle and Denebola in the eastern part of Leo are of the second. Here too there are many telescopic objects of great interest. With Virgo, the Virgin, we come to an area rich in faint galaxies; the 'bowl' outlined by some of the brightest stars is crammed with faint systems, though of course photographs taken with large telescopes are needed to show them properly. Virgo is a very large constellation, and has one star, the white Spica, of the first magnitude.

Between Virgo and the next brilliant Zodiacal constellation, Scorpio (or Scorpius) lies Libra, the Balance, once known as the Scorpion's Claws. This is probably the most obscure of all the Zodiacal groups; it has no bright stars, and relatively few telescopic objects of interest. However, Scorpio more than makes up for Libra's deficiencies. The leading star, Antares, is a brilliant red supergiant, and one can understand how the long chain of stars of which Antares is a member reminded the ancients of a scorpion. Unfortunately, the brilliant 'sting' is so far south that it never rises in Britain. One of its stars, Shaulah, is only just below the first magnitude.

Adjoining Scorpio is Sagittarius, the Archer, southernmost of the Zodiacal groups; it has many fairly bright stars, but no distinctive shape, and it is always inconveniently low in British skies. Then come Capricornus, the Sea-Goat, and Aquarius, the Waterbearer, both of which are extensive and rather faint. Finally we come back to Pisces, which, since it now contains the Vernal Equinox, should properly be regarded as the first constellation of the Zodiac instead of the last. Truly, these Zodiacal groups are varied; but each has its own points of special interest.

February

Full Moon: February 2 *New Moon:* February 16

Mercury is at greatest western elongation on February 23 (27 degrees), but is then well south of the Sun and is unlikely to be seen, as it is too low in the bright sky at dawn.

Venus is a brilliant evening star (magnitude −4·1 to −4·3) and continues to set about four hours after the Sun. Venus is moving eastwards towards Saturn, but it does not reach that planet, since it comes to a stationary point in March and then turns back again. It will, however, pass Saturn in June when both planets are morning stars.

Mars is a morning star, rising about an hour after midnight, and growing brighter as its distance from the Earth decreases (magnitude +1·1 to +0·6). It is moving direct in Libra, and at the end of the month will be seen on the borders of Libra and Scorpius. Mars will pass about half a degree south of Neptune on the night of February 22 (see diagram on page 52).

Jupiter is a brilliant evening star, rising in the late evening in Virgo (magnitude −1·8 to −2·0). It is now approaching opposition, and this is a favourable opportunity to watch the phenomena of the four big satellites, which may easily be seen with a small telescope. All four satellites undergo eclipse (to the west of the planet) during the month.

Saturn sets in the west before midnight. Venus also sets at about the same time, but this planet is much brighter than Saturn, and will be seen farther round to the north of west.

The Brightest Stars in Orion. Orion, the Hunter, is one of the most glorious of all the constellations. It has many bright stars, as well as its Great Nebula and many telescopic objects of immense

interest. Many legends are attached to it, and it is, of course, one of the original groups.

When Johann Bayer allotted Greek letters to the stars, in his catalogue published in 1603, he gave the letter Alpha to Betelgeux, the red star in the Hunter's shoulder, and Beta to Rigel in the 'foot'. Rigel is, however, the brighter of the two. It is markedly outshone only by Sirius of the stars visible in northern skies; Arcturus, Vega, Capella and Rigel are all practically equal, and are of roughly zero magnitude.

Of these four Rigel is by far the most luminous. It is the equal of perhaps 50,000 Suns; the exact value is naturally rather uncertain, because Rigel is so far away. We are seeing it not as it is now, but as it used to be about the time of the Battle of Hastings. Telescopically it is a fine sight, and a 3-inch refractor will suffice to show its faint companion-star.

Betelgeux is entirely different. Its name may be spelled in several different ways (Betelgeuse and Betelgeuze are other variations) and the pronunciation is often given, picturesquely though inaccurately, as 'Beetlejuice'! The name is Arabic, as are many of the star-names in use today.

Betelgeux is not so luminous or so remote as Rigel, but it is of tremendous size, and its diameter is about 250,000,000 miles, so that it could easily hold the entire orbit of the Earth round the Sun. This diameter is not constant, because Betelgeux is an intrinsic variable star. It swells and shrinks, and its magnitude changes within rather narrow limits. At times it may almost equal Rigel, while at others it is not much brighter than Aldebaran, the red star in Taurus which makes an excellent comparison.

There are many variable stars in the sky, but Betelgeux is the brightest of them (unless we include the remarkable southern-hemisphere object Eta Carinæ, which for a time in the last century outshone every star except Sirius, but which for decades now has been too faint to be seen with the naked eye, and may not be a normal variable star). Betelgeux's variations are slow, and not too easy to follow, but over a period of weeks they can be tracked. There is a rough period of about five years, and maximum occurred

during early 1968, but this period is very erratic indeed, and we can never predict quite what Betelgeux will do next.

Mars and Neptune. Neptune, the outermost of the giant planets, was discovered in 1846. It was located because of the pull it exerted on the planet Uranus, which had been discovered by Herschel in 1781. Neptune, of course, is too faint to be seen with the naked eye; its mean opposition magnitude is 7·7. Binoculars will show it, but without a moderate telescope it looks exactly like a star, and considerable power is needed to bring out its pale, rather bluish disk.

This month will provide a good chance for locating Neptune, because on February 22 it will be only about half a degree away from Mars and therefore in the same low-power field. There should be no difficulty in identifying Neptune, which remains the outermost member of the main planetary system.

A Normal February. 1968 was Leap Year, since it was exactly divisible by four. 1969 is not a Leap Year, and so February has its normal 28 days. Certainly our calendar is decidedly inconsistent and irregular; there have been many suggestions in the past for amending it to a more logical 'world calendar', but these suggestions have never aroused much enthusiasm, and it does not look as though any steps will be taken about them in the foreseeable future.

March

Full Moon: March 4 *New Moon:* March 18

Equinox: March 20

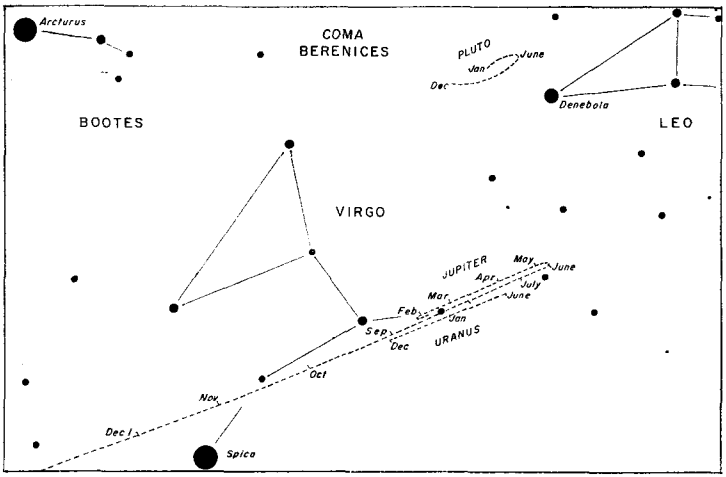
Mercury is now approaching superior conjunction and is not visible.

Venus is an evening star, reaching its greatest brilliancy (magnitude −4·3) on March 3. The planet is at a stationary point on March 17 and after this date its retrograde motion carries it rapidly in towards inferior conjunction, so that by the end of the month it sets north of west only about an hour after the Sun; it is then only of magnitude −3·6.

Mars rises just before midnight and is now growing rapidly brighter (magnitude +0·6 to −0·2) as its distance decreases. In the first half of the month Mars passes through the bright stars in Scorpius, and will then move into Ophiuchus. It will be about 6 degrees north of *Antares* on March 17, and this will afford an opportunity to compare the colours of Mars and *Antares* (the 'rival of Mars'), although Mars is a full magnitude brighter than the star.

Jupiter is at opposition on March 21 and is therefore visible all night; it will be seen in the east just after sunset, and sets in the west at dawn. The planet is now at its brightest (magnitude −2·0) and is easily recognized among the stars of Virgo. At its nearest to the Earth on March 23, Jupiter will be at a distance of 414,000,000 miles. It is now close to the equator, and for the next few years it will be lower in the sky and oppositions will be less favourable. The eclipses and other phenomena of three of the four satellites of Jupiter continue, but the tilt of Jupiter towards the Earth has now increased, so that satellite IV no longer transits the face of the planet or undergoes eclipse or occultation; the last

eclipse of this satellite during the year occurs on March 4 at 3^h G.M.T. Jupiter passes less than a degree north of Uranus on March 15.



Jupiter, 1969

Saturn is still moving direct in Pisces, and may be seen in the south-west after sunset. It sets in the west about three hours after the Sun at the beginning of the month, but this interval decreases rapidly because Saturn sets earlier and the Sun sets later each evening. The planet Venus will be seen some degrees to the right (north) of Saturn (magnitudes: Saturn +0·8, Venus −4·3).

Uranus is at opposition on March 22 and will then be at a distance of about 1,610,000,000 miles. Its position in Virgo is shown on the diagram above and it will be seen that it is never far from Jupiter during the first half of the year; it will be easy to find at the time of conjunction with Jupiter on March 15. The magnitude of Uranus at opposition is +5·7, and it should be just possible to see it with the naked eye; in a small telescope it appears as a greenish disk.

Pluto is at opposition on March 14 on the borders of Libra and Coma Berenices (see diagram on page 59). The planet is too faint to be seen with small instruments, since its magnitude is about +14. Its distance at opposition is about 2,870,000,000 miles.

An *annular eclipse of the Sun* on March 18 will not be visible in northern latitudes (see page 95).

The Sun Moves North. On March 20 the Sun reaches the First Point of Aries or Vernal Equinox – now located not in Aries but, due to precession, in the adjacent Zodiacal constellation of Pisces. From now until the latter part of September the Sun will remain north of the celestial equator.

Around this time Great Britain used to change over to Summer Time, by advancing the clock by one hour ahead of G.M.T. and so giving lighter evenings – though, of course, darker mornings. This was first introduced more than half a century ago, and aroused great controversy. The Rev. M. A. Ellison, former Director of the old-established observatory at Armagh, once officially described Summer Time as 'this freak of the House of Commons'. During the last war, Summer Time was in force all the year round, with Double Summer Time – two hours ahead of G.M.T. – in summer. Then, after the end of hostilities and the abandonment of the wartime blackout regulations, things reverted to what had become accepted as the norm.

The decision to change over to permanent Summer Time, unsuitably renamed Standard Time, was taken in 1966, and again aroused great controversy. The regulation came into force in February 1967, when the clocks were put on an hour and not put back again in the autumn, as had always been done before.

Criticisms have been fierce, and there are certainly two schools of thought which are diametrically opposed to each other. It is too early as yet to tell whether the experiment will be continued permanently, but for the moment, at least, Standard Time is here to stay.

The Rival of Mars. Mars has now become a very conspicuous object, and its magnitude during the month rises to above zero. It

is close to Antares in mid-March, and this will be a good chance to compare the two, though Mars is of course a magnitude the brighter.

Antares is a particularly large and luminous Red Giant of spectral type M. Its name really means 'The Rival of Mars' – the Greek name for Mars was Ares. The best instrument to use for this purpose is a pair of binoculars, because anything more powerful will show Mars as a definite disk instead of a point of light, so that it will be less easy to effect direct comparisons with Antares.

An Annular Eclipse. There can be no doubt that a total eclipse of the Sun is the most spectacular sight in all Nature. As the last portion of the solar disk vanishes, and the corona and the prominences flash into view, the effect is magnificent by any standards.

Unfortunately, total eclipses as seen from any particular point on the Earth's surface are rare; in England the last to be seen was in 1927 and the next will not be until 1999 (though the total eclipse of 1954 could just be seen off the North Scottish islands; the belt of totality extended into Scandinavia). With an annular eclipse neither the corona nor the prominences can be seen. The Moon is not quite large enough in apparent diameter to cover the Sun, and so a ring of sunlight is left showing – hence the name; Latin *annulus*, a ring.

For this reason, annular eclipses are not regarded as astronomically important in comparison with total eclipses, and no major expeditions are usually dispatched to observe them. All the same, they are spectacular in their own way, and are very well worth seeing. It is a pity that this month's phenomenon is invisible from Europe; in fact, there is no annular eclipse to be seen from Britain for many years, though there will be a number of partial solar eclipses.

Venus at its Brightest. Venus is at its maximum brilliancy during March. Telescopically it appears as a crescent, as it always does when at its brightest; when more of the sunlit face is visible, the planet is farther away from us, and this more than compensates for

the greater phase. When at its best, it may cast a perceptible shadow, and it easily outshines its nearest planetary rivals, Jupiter and Mars. Keen-sighted people can see Venus when the Sun is well above the horizon, and there are many authentic cases of the crescent phase having been seen without optical aid.

April

Full Moon: April 2 *New Moon:* April 16

Mercury is in superior conjunction on April 8, but begins to be visible again as an evening star at the end of the month, when it will be seen north of west after sunset. For further details and diagram, see May Notes.

Venus moves rapidly in towards inferior conjunction on April 8, after which it moves out again from the Sun to become a morning star. At the end of April Venus rises in the east about an hour before the Sun, and it is then of magnitude −4·1.

Mars rises at midnight at the beginning of April. It is quite a bright object (magnitude −0·2 to −1·1) and is easily recognized in that part of the constellation Ophiuchus which intrudes into the Zodiac between Scorpius and Sagittarius. Mars now appears to be moving more slowly, and it reaches a stationary point on April 27, after which it moves in the retrograde direction as it approaches opposition at the end of May. In the course of its actual motion in space, Mars is at the descending node of its orbit on April 21; it is then moving most rapidly from north to south of the ecliptic, and as a result the apparent path takes on an S-shape (see diagram on page 52) instead of the more familiar loop.

Jupiter is visible throughout the evening but now sets before sunrise. Still a brilliant object (magnitude −2·0 to −1·9) it will be seen near the Moon on April 1 and 29; the Moon passes to the south of the planet each month, but will be closest in April and May. A small telescope will show that the satellite IV now passes above (north of) the planet at each inferior conjunction and below (south) at superior conjunction, so that this satellite is at all times easily visible; this continues throughout the year (see March Notes).

Saturn is in conjunction on April 18 and is not visible during the month.

A penumbral eclipse of the Moon on April 2 will be visible in Europe (see page 95). In a penumbral eclipse the change in the light of the Moon is very small, and the phenomenon is unlikely to be seen with the naked eye.

Penumbral Eclipse of the Moon. During a lunar eclipse, the Moon passes into the shadow cast by the Earth; its direct supply of sunlight is cut off, and the Moon becomes dim, often coppery in hue, until it passes out of the shadow again. These lunar eclipses have been watched with interest, and originally with some alarm, ever since the earliest days of human history. Astronomically they have been regarded as important since the start of the Space Age. As the Earth's shadow passes over the Moon, a wave of cold sweeps across the lunar surface, and measures of the fall in temperature are very valuable in investigations of the nature of the lunar surface.

The main cone of shadow cast by the Earth is called the umbra (a term which has no connection with the umbra or central area of a sunspot). But since the Sun is a disk, and not a point source, there is an area of what may be called partial shadow, or penumbra, to either side of the umbral cone. The Moon must pass through this penumbra before entering the umbra. This month, however, on April 2, the Moon will pass only through the penumbra, and will miss the main cone altogether, so that we have what is called a penumbral eclipse.

With a telescope, or even binoculars, the dimming will be quite evident. Measures made during recent eclipses by members of the Lunar Section of the British Astronomical Association have shown that the penumbra is detectable without much difficulty, and the phenomenon will be well worth watching, even though it will not be at all spectacular. There will not be another umbral lunar eclipse visible from Britain until August 1970.

The Jovian Satellites. Jupiter is now well placed for observation. It lies in Virgo, but next year it will have moved farther south, so that it will not be so high in British skies as it is at the moment.

The four large satellites are favourite objects for observation with a small telescope. They are named Io, Europa, Ganymede and Callisto in order of distance from the planet, even though these proper names are not always used and numbers are given instead – which is rather curious, since all other satellites in the Solar System are named apart from the rest of Jupiter's family, and every tiny asteroid whose orbit has been satisfactorily worked out is also dignified by a proper name.

Io and Europa are about the size of our Moon, but Ganymede and Callisto (Nos. 3 and 4) are decidedly larger. They may in fact have diameters as great as that of the planet Mercury, though they are appreciably less massive. No atmospheres round any of the Jovian satellites have been confirmed, but Ganymede, the most massive of them, might reasonably be expected to have some sort of an atmosphere, albeit a very tenuous one.

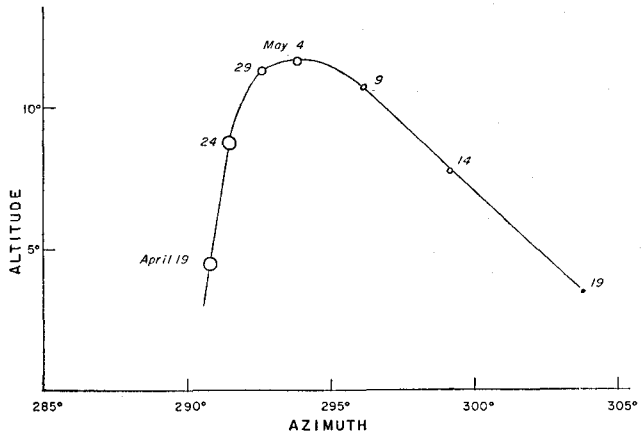
Telescopically the four satellites show perceptible disks, but markings on them cannot be seen with small or moderate telescopes – despite some curious recent claims to the contrary! Their eclipses, occultations, transits across Jupiter and shadow transits are fascinating to watch, though Callisto, the most distant from Jupiter, is not now showing these phenomena, and will not do so for the rest of the present opposition.

A Famous Belgian Astronomer. April 29 is the hundredth anniversary of the birth of Georges Lecointe, a celebrated Belgian astronomer. He was born in Antwerp, and after a military career he joined the staff of Uccle Observatory; subsequently he became Director, and undertook much valuable work in connection with planetary observation, star cataloguing and stellar distribution. He died on May 27, 1929.

May

Full Moon: May 2 and 31 *New Moon:* May 16

Mercury is at greatest eastern elongation on May 5 (21 degrees) and is then well placed for observation as an evening star. The diagram shows the changes in altitude and azimuth (true bearing from the north through east, south and west) of Mercury on successive evenings when the Sun is 6 degrees below the horizon; this will be about 40 minutes after sunset at this season. The



Mercury, April–May 1969

changes in brightness are roughly indicated by the size of the circles, and it will be seen that Mercury is brightest before the date of elongation.

Venus is again at greatest brilliancy (magnitude −4·2) on May 14, when it rises about 1½ hours before the Sun. It moves only slowly out from the Sun, and as the ecliptic is low in the sky on these summer mornings, Venus will not make such an impressive appearance as it may do at an autumn elongation.

Mars is at opposition on May 31 and will be visible all night. Although moving retrograde some degrees north and east of *Antares* the planet is still in Ophiuchus and its brilliance makes it easy to recognize (magnitude −2·0). Mars is low in the sky, but this is quite a favourable opposition; the north pole of the planet is slightly tilted towards the Earth, and this is the end of summer in the Martian northern hemisphere. On the night of opposition, Mars, *Antares* and the Full Moon will form an interesting group.

Jupiter is visible until the early hours of the morning in the south-western sky. It is now fading a little (magnitude −1·9 to −1·7), and its retrograde motion becomes slower until it reaches a stationary point on May 23 near the star Beta Virginis (see diagram on page 59).

Saturn now begins to appear as a morning star, and by the end of May it rises in the east about an hour before the Sun. Its magnitude is only +0·7, and it will be difficult to see in the bright dawn sky; Venus is to be seen in the same part of the sky, but this planet is very much brighter, and at a greater altitude.

Neptune is at opposition on May 18 in Libra. Although not visible to the naked eye (magnitude +7·7) its position is shown on the diagram on page 52. At opposition, the distance of Neptune from the Earth is about 2,730,000,000 miles.

Mercury as an Evening Star. Mercury is the smallest and most elusive of the naked-eye planets. It is only about 3,000 miles in diameter, so that it is not a great deal larger than the Moon; its mean distance from the Sun is a mere 36,000,000 miles, and it has a sidereal period of 88 days.

Because it always seems close to the Sun in the sky, it can be seen with the naked eye only when low in the west after sunset or low in the east before sunrise. It is never very conspicuous, and it is rather surprising that the ancients knew it so well. Yet when Mercury is located, it may seem quite surprisingly bright, and one wonders how it can have been overlooked!

There is a story, probably untrue, that the great theoretical astronomer Copernicus never saw Mercury in his life. However, from Britain it should be easily visible this month, provided that the sky near the horizon is free of mist and cloud. Sweeping for it with binoculars is a good method, but should not be attempted until the Sun has actually set. Otherwise, the Sun may come into the binocular field, with disastrous results to the observer's eyesight.

Mercury has been carefully studied of late, and there have been some unexpected findings with regard to its rotation period. These are described by V. A. Firsoff in the article section of the present *Yearbook*.

The Great Bear. During May evenings the constellation of Ursa Major, the Great Bear, is practically overhead. Most people know it by its nickname of the Plough, though the seven Plough stars make up only part of the complete constellation. It never sets over Great Britain or the northern United States, so that it is always to be seen somewhere or other whenever the sky is sufficiently dark and clear.

The seven stars are named Alkaid, Mizar and Alioth (in the tail), Megrez (the faintest of the seven), Phad, and Merak and Dubhe (the pointers to the Pole Star). There are various forms of these names; Alkaid is also known as Benetnasch, Phad as Phecda or Phekda. Astronomers prefer to call them by their official names of Eta, Zeta, Epsilon, Delta, Gamma, Beta and Alpha Ursæ Majoris.

Mizar is easy to pick out, because it has a much fainter star, Alcor, close beside it. It is said that the Arabs used to regard this as a naked-eye test, but it is not so at the present time, as Alcor is easily visible on a clear night to anyone with normal eyes. Telescopically, Mizar is itself seen to be a wide, easy double. Alcor lies in the same low-power field, and between it and the Mizar pair is another star, not actually connected with the group.

The Greek astronomers of 2,000 years ago recorded that Megrez was equal to its companions, but it is now more than a magnitude

fainter, and it may therefore have faded perceptibly since Classical times. The magnitude of Megrez is well below 3, while Alkaid, Alioth and Dubhe are fully second magnitude.

Two of the Plough stars, Alkaid and Dubhe, are moving in a direction different from that of the remaining five, and eventually the characteristic shape will be distorted; but the proper motions of the stars are so slow that to all intents and purposes the Plough looks just the same now as it did when the Egyptian Pyramids were built—and it will still look the same in, say, 5,000 years hence. Certainly the northern skies would look strange without the familiar Great Bear.

Retrograde Motions of Planets. This month both Mars and Jupiter are moving in a retrograde direction among the stars; that is to say, east to west instead of west to east. Of course, this does not indicate any actual reversal in motion; it is the result of the combined movements of the Earth and the planets concerned. Jupiter reaches its stationary point on May 23, and subsequently it will resume its eastward path. It is also going south, so that in 1970 it will be less well placed for northern observers.

June

New Moon: June 14 *Full Moon:* June 29

Solstice: June 21

Mercury is at greatest elongation west (morning star) on June 23 (23 degrees), but is unlikely to be seen, since it is well south of the Sun and too low in the bright dawn sky.

Venus comes to greatest elongation west (morning star) on June 17 (46 degrees). It now rises 1½–2 hours before the Sun, but the sky is not really dark at this time of year. On June 11 Venus passes about a third of a degree south of Saturn (magnitudes: Saturn +0·7, Venus −4·0), and on that morning both planets will be seen a few degrees south of the waning crescent moon.

Mars is at its nearest to the Earth (45,000,000 miles) on June 9, but it will come even closer at the opposition of 1971. During the month Mars moves into Scorpius and again passes north of *Antares* on June 3 (see diagram on page 52); but now the two objects are more difficult to compare, since Mars is very much brighter (magnitudes: *Antares* +1·2, Mars −1·9). The planet will be seen in the south about two hours after sunset, and it sets in the early hours of the morning.

Jupiter is still a bright evening star (magnitude −1·7 to −1·6) but sets at midnight at the end of the month. The planet will be seen close to the crescent Moon on the night of June 22, and Uranus will be even closer, but will be difficult to see in the summer night sky.

Saturn is a morning star and by the end of June it rises an hour after midnight; it is now moving direct in Aries, and will be seen in the east in the morning sky below *Hamal*. On June 11 Venus passes close to Saturn, and this conjunction is referred to in the note above.

The Celestial Harp. During summer evenings the brilliant bluish star Vega is almost overhead as seen from Britain or the northern United States. It cannot be mistaken, since it is far brighter than any of its neighbours. Its magnitude is only fractionally below zero, and it easily outshines the two other members of the so-called Summer Triangle: Altair in Aquila (the Eagle) and Deneb in Cygnus (the Swan).

Actually, Vega is much less luminous than Deneb. Vega is the equal of 50 Suns, but a conservative estimate makes Deneb equal to 10,000 Suns. Altair, however, is one of our nearest neighbours, and is not so powerful as Vega.

Vega is the leader of the little constellation of Lyra, the Lyre or Harp. Small though it is, Lyra contains much more than an average share of interesting objects. First, perhaps, comes the famous multiple star Epsilon Lyræ, which lies close to Vega. Keen eyes can separate it into two components; a 3-inch refractor is capable of showing that each component is again double, so that we have an easy quadruple star. The system really is an associated group, and is probably the most spectacular of its kind in the sky.

Apart from Vega, the two brightest stars in Lyra are Beta and Gamma, both of which are of roughly the third magnitude. Beta is a celebrated variable, and though it sometimes rivals Gamma it is usually fainter. Strictly speaking it is not variable at all; it is an eclipsing binary, with its two components so close together that no telescope will separate them. It seems that each component must be pulled out into an ellipsoidal or egg-shape, and the whole system is associated with extensive shells of gas. Beta Lyræ is not unique; others of its kind are known, but this particular star has been of immense interest and value to astrophysicists.

Between Beta and Gamma lies the planetary nebula M.57 (the 57th object in Messier's catalogue of clusters and nebulæ compiled during the latter part of the 18th century). This is not really a nebula, and it is certainly not a planet. It is a faint star with a vast gaseous surround, and it looks rather like a faint, luminous ring when seen with large telescopes, which has led to its common name

of the Ring Nebula. Small instruments will show it, but not very clearly, and the central star is a very difficult object.

Also in Lyra are various doubles; mention should also be made of the red variable R Lyræ, which varies between magnitudes 4 and 5, and is an excellent object for study with wide-field binoculars. Altogether, this little constellation is exceptionally rich in interest.

Midsummer Day. In Britain, Midsummer Day is always associated with the prehistoric monument at Stonehenge. It has been claimed that this great stone structure was designed as a primitive form of computer, mainly for predicting eclipses. This was the theory proposed some years ago by G. S. Hawkins, who undertook extensive investigations. Initially, Hawkins' theory was widely criticized, but recent studies seem to support it. If it is correct, then we must assume that the Stonehenge-builders knew far more about astronomy than we had thought.

The date of Stonehenge is known with fair accuracy. Construction was begun about 1800 B.C., and the final phase of building was complete by 1300 B.C., so that it was very ancient even in Julius Cæsar's time. On the whole it is in a good state of preservation, and it has become very much of a tourist attraction.

In the popular mind Stonehenge is always associated with the Druids, but there is no justification whatsoever for this. It was old when the Druid cult first came to Britain; there is no evidence that the Druids paid any special attention to it, and there is good evidence that they did not, since it was not the kind of monument with which they would actually be associated. There is, in fact, no connection at all between the monument and the British Druids.

There is one distressing fact which cannot be ignored. Acts of vandalism have been perpetrated at Stonehenge, and in early 1968 some of the stones were daubed with red paint, as part of a student University 'rag'. This sort of behaviour cannot be too strongly condemned, and it is to be hoped that a more adult attitude will prevail in the future. Stonehenge, after all, is unique – and can never be replaced.

July

New Moon: July 14 *Full Moon:* July 29

Earth is at aphelion (farthest from the Sun) on July 5, when its distance from the Sun is 94,550,000 miles.

Mercury is in superior conjunction on July 22 and will remain invisible throughout the month.

Venus rises about an hour after midnight, nearly three hours before the Sun, but the planet is now losing a little of its brilliance (magnitude −3·9 to −3·6). On the morning of July 16, Venus passes about 3 degrees north of *Aldebaran* (magnitude +1·1) but, as the sky is not completely dark, this may be difficult to see.

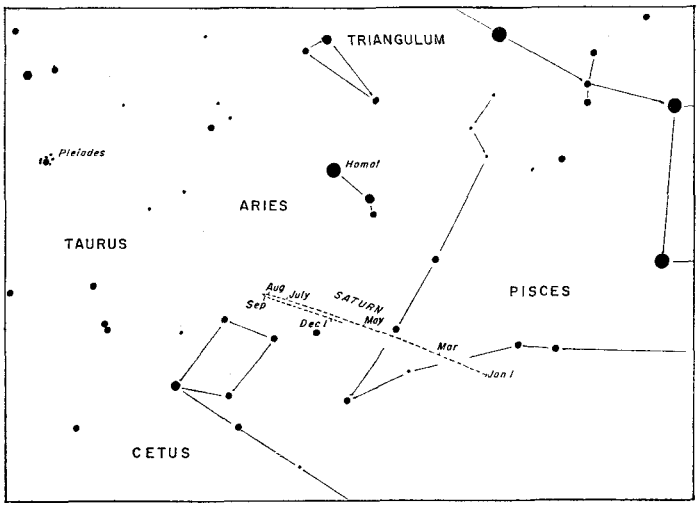
Mars is an evening star and will be in the south at sunset at the end of the month. The planet rapidly loses in brightness as its distance from the Earth increases (magnitude −1·6 to −0·9), and this change should be quite appreciable to the naked eye. Mars reaches a stationary point on July 8 in the northern part of Scorpius; after this date the motion is again direct, but the apparent path does not form a loop this year (see April Notes).

Jupiter sets in mid-evening and continues to fade as it approaches conjunction in September (magnitude −1·6 to −1·4). Jupiter again passes Uranus on July 18, but the bright sky may prevent observation (Jupiter 0·6 degree north of Uranus).

Saturn is a morning star, rising at midnight at the beginning of July, and growing a little brighter (magnitude +0·6 to +0·5).

Alcock's Nova. A year ago in July 1968, the British amateur G. E. D. Alcock of Peterborough, discovered a nova, or new star, in the constellation of Delphinus. This represented a triumph for careful, systematic observation, because the nova was not found by

accident. Alcock had undertaken a regular nova search, and his extensive knowledge of the stars enabled him to recognize the newcomer at once. Immediately he telephoned the Royal Greenwich Observatory, and the discovery was confirmed there. Alcock had



Saturn, 1969

already discovered three comets, but Nova Delphini was much his most important 'find' to date, and great credit is due to him. Incidentally, the nova has been of exceptional interest owing to its long maximum, even though it never became a striking naked-eye object. In 1968 he discovered a second nova.

Alcock is one of those amateur astronomers in the great tradition. Night after night he searches the sky with his binocular equipment, and if any interesting comet or nova appears he may be expected to identify it quickly – as he did on this occasion. But activities of this sort take immense time and patience. Alcock spent many years in 'learning the stars', until by now he can recognize many thousands of them, and his knowledge of the star-patterns is probably unequalled. By profession he is a schoolmaster, teaching in Peterborough.

The Earth at Aphelion. On July 5 the Earth reaches its greatest distance from the Sun. This occurs, of course, in the middle of summer in the northern hemisphere, but the changing distance from the Sun has only a minor effect upon the seasons, because the Earth's orbit is so nearly circular. More important is the land-and-sea distribution, though in theory the southern summer is slightly shorter and hotter than the northern, while the winter is longer and colder.

The axial tilt of the Earth amounts to $23\frac{1}{2}$ degrees, and it is this which gives rise to the seasons. Of the other planets, Mars has a tilt only slightly greater, so that the seasons are of the same basic type even though the 687-day Martian 'year' means that they are much longer. Jupiter, on the other hand, has a tilt of only 3 degrees, and there can be no analogous seasons, though this makes little difference in view of the fact that the surface temperature is always so low. With Uranus, the tilt is 98 degrees; more than a right angle, so that the 'seasons' there are most peculiar, and each pole has a day and a night each lasting for 21 Earth-years. The reason for this strangely high axial inclination is unknown; it is not shared by Neptune, outermost of the giant planets.

Sagittarius, the Archer. July evenings give a suitable time to look for Sagittarius, southernmost of the Zodiacal constellations. It contains many fairly bright stars, but the lack of any well-marked outline makes it difficult to identify at first sight. Part of it is too far south to rise over Britain or New York. Curiously, Alpha and Beta Sagittarii, dignified by the first two letters of the Greek alphabet in Bayer's list of 1603, are well south, and are relatively faint; the two brightest stars in the constellation have been given the Greek letters Epsilon and Sigma. Of these, only Sigma, also known by its old proper name of Nunki, attains a respectable altitude in European latitudes.

The Brightness of Saturn. Saturn is now becoming more prominent, and its brightness rises to magnitude 0·5, so that it is now more brilliant than most of the stars. This year the rings are opening, and

so the planet is more striking than in 1966, when the ring-system was edge-on. At this time the naked-eye brightness was less than usual, because Saturn's rings are considerably more reflective than the globe.

August

New Moon: August 13 *Full Moon:* August 27

Mercury approaches eastern elongation at the end of the month, but it is then well south of the Sun and too low in the sky to be seen in these latitudes.

Venus is a brilliant morning star (magnitude −3·6 to −3·5), rising more than three hours before dawn. At the end of the month it may be seen in a dark sky below the Twins, *Castor* and *Pollux*.

Mars is still a bright object in the evening sky, but is now rapidly fading (magnitude −0·9 to −0·4) and sets before midnight. The planet is moving direct and passes into Ophiuchus again about August 8. On August 12 Mars is in conjunction with *Antares* for the third time this year, and will be seen only a little more than a degree north of the star (magnitudes: Mars −0·7, *Antares* +1·2). On the evening of August 21 the Moon, just past First Quarter, will be in the same neighbourhood, forming a pleasing triangle of three objects of contrasting brightness.

Jupiter now sets in the west about an hour after the Sun, but is still bright enough (magnitude −1·4 to −1·3) to be seen in the twilight.

Saturn now rises in the east in mid-evening. It reaches a stationary point on August 22, and as will be seen from the diagram on page 74 there is no other stationary point in the path this year (the next one occurring in 1970 January) so that there is no loop in the path in 1969. The planet is growing a little brighter (magnitude +0·5 to +0·4) as it comes nearer to the Earth.

A penumbral eclipse of the Moon on August 27 is of very small magnitude and will not be visible in the British Isles (see page 95).

The August Perseids. Every August the Earth passes through the Perseid meteor swarm, and the result is a rich shower of shooting-stars. Though the Perseids cannot match the occasional splendour

of the November Leonids, they never fail us, and when the Moon is out of the way – as happens this year – the shower is quite spectacular.

There is an essential difference between a shooting-star meteor, which is a tiny particle usually smaller than a grain of sand, and a meteorite, which is a much larger body more nearly associated with the asteroids. Meteors such as the Perseids are destroyed before they hit the ground, and are of extremely small mass. During the first part of August they should be well seen, particularly after the Moon has waned into a crescent. Amateur photographs may well try to 'catch' some of them. The procedure here is to point the camera somewhere in the direction of the radiant, in Perseus, and simply leave the shutter open. If a bright meteor happens to flash across the field of view, it will be duly recorded – and with an exposure of more than ten minutes during the maximum of the shower the chances are extremely good.

Hercules. In mythology Hercules was one of the great heroes, and his Labours must have been read by almost everyone. Naturally, he is in the sky – and yet for some reason he is not so bold and striking as might be expected. In fact Hercules is an obscure group, even though the area covered is large. There are only two stars as bright as the third magnitude, and neither is the outline very distinctive.

Yet there are various features of interest. Alpha Herculis, or Rasalhague, is not the brightest star in the constellation, but it is strongly red in colour, and is variable in light, fluctuating between magnitudes 3 and 4. It is comparable with Betelgeux in Orion, but is not so conspicuous, because it is farther away. Telescopically it is seen to have a faint companion which is decidedly greenish in hue – though this colour is due partly to contrast with the redness of the bright primary.

Another feature of Hercules is the globular star-cluster which lies between Eta and Zeta, rather closer to Eta. It is just visible to the naked eye on a clear night, and binoculars show it clearly. Telescopically it is magnificent, since it is seen to be composed of

vast numbers of stars arranged in a spherical system. This cluster, known as M.13 because it was the thirteenth entry in the famous catalogue of clusters and nebulæ drawn up by Charles Messier in 1781, is the brightest globular cluster visible from Europe or North America. It is surpassed only by Omega Centauri and 47 Tucanæ, which are far south in the sky.

Adjoining Hercules is another large, rather faint constellation: Ophiuchus, the Serpent-Bearer, whose leading star, Rasalgethi, lies close to Rasalhague and is a magnitude brighter. Ophiuchus seems to be engaged in a life-or-death struggle with Serpens, the Serpent. The wrestler is apparently having the better of things, because Serpens has been divided into two separate parts, Caput (the Head) and Cauda (the Body). Between them Hercules, Ophiuchus and Serpens cover a very large part of the sky, and this is a noticeably barren area. To one side of it lies Vega, the brilliant blue star in Lyra; to the other, Antares in the Scorpion.

Incidentally, Ophiuchus intrudes into the Zodiac, though it is not officially ranked as a Zodiacal constellation. Mars enters it on August 8, and is much brighter than any of the stars in the group, even though it is now fading rapidly as it recedes from the Earth and is little above zero magnitude by the end of the month.

September

New Moon: September 11 *Full Moon:* September 25

Equinox: September 23

Mercury is at greatest elongation (evening star) on September 3 (27 degrees), but its altitude will be very small, and it is not likely to be seen. Inferior conjunction occurs on September 29.

Venus still rises in a dark sky about three hours before sunrise. The planet moves into Leo during the month and will pass less than half a degree north of *Regulus* on September 22 during daylight hours; it will be seen quite close to that star before dawn on that day.

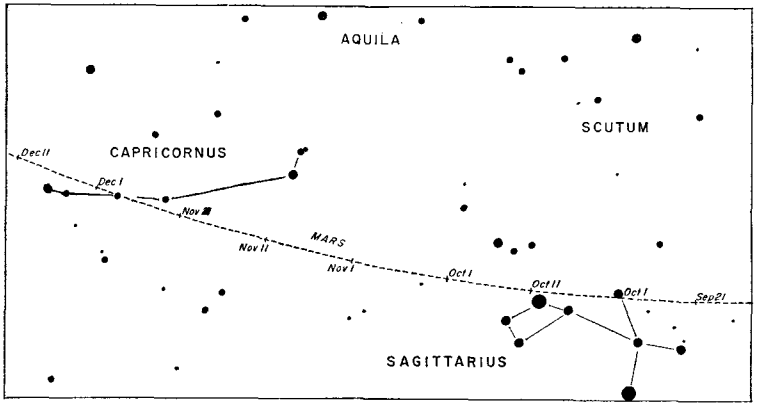
Mars is an evening star, and moves into Sagittarius in the middle of the month. At the end of the month it is twice as far from the Earth as it was in early June, and as a result its brightness diminishes still further (magnitude −0·4 to 0·0). Mars reaches the most southerly point in its apparent path on September 26 (see diagram on page 81), and after this date its increasing northerly movement combined with its direct motion to the east causes it to set about the same time each evening (about 22^h) for the rest of the year.

Jupiter is now quite close to the Sun as it approaches conjunction, so that it is not likely to be seen. It may be of interest to note that Jupiter is at its greatest distance from the Sun (aphelion) on September 3. This distance is 507,000,000 miles, which is 47,000,000 miles more than the perihelion distance, when Jupiter is in Pisces. The effect of this increase in distance is to reduce the brightness of the planet by 0·2 magnitude.

Saturn now rises an hour or two after sunset and is visible for most of the night in a dark sky. It continues to grow brighter, and reaches magnitude +0·2 by the end of September.

An annular eclipse of the Sun on September 11 will not be visible in the British Isles, but will give rise to a partial eclipse in North America (see page 95).

A penumbral eclipse of the Moon of large magnitude on September 25 reaches its maximum at 20^{h} G.M.T., but this phenomenon is not generally visible to the naked eye (see April Notes and page 95).



Mars, September to December 1969

Harvest Moon. On September 23 the Sun reaches the equator at the Autumnal Equinox, or First Point of Libra (now actually situated in the preceding Zodiacal constellation, Virgo). For the next six months the Sun will remain in the southern hemisphere of the sky. Two days later the Moon is full, and we come therefore to the time of the Harvest Moon, which is the first full moon after the Autumnal Equinox.

At most times in the year the Moon rises at least half an hour later from one evening to the next, and at some periods this *retardation* may amount to more than an hour. At Harvest Moon, however, the retardation is no more than about 15 minutes (though it is incorrect to say, as many books do, that at Harvest Moon time

the full moon rises at the same hour for several evenings in succession). The reason for this is that at such times the ecliptic makes its sharpest angle with the horizon. There is no significance in the phenomenon, and neither does the Harvest Moon look larger than any other full moon – this is another popular misconception, as careful measurement will soon show.

The Pleiades. During late evenings in September the magnificent cluster of the Pleiades becomes visible in the east, heralding the approach of autumn. The nickname for the cluster is 'the Seven Sisters', and it is true that seven is the average number of stars visible to a normal-sighted person on a clear night; but people with keen sight can see more, and the record is said to be nineteen. The names and magnitudes of the leaders are:

Alcyone	(η Tauri),	mag. 2·87
Atlas	(27 Tauri),	3·64
Electra	(17 Tauri),	3·71
Maia	(20 Tauri),	3·88
Merope	(23 Tauri),	4·18
Taygete	(19 Tauri),	4·31
Pleione	(28 Tauri),	5·09
Celæno	(16 Tauri),	5·46
Asterope	(21 Tauri),	5·76

Of these, Pleione is somewhat variable, and is one of the extraordinary 'shell stars', though telescopically it looks perfectly ordinary.

The Pleiades cluster is the finest of its kind in the sky, and is of course a genuine system. Intermixed with the cluster stars is extensive nebulosity, shining by reflected starlight and known therefore as a reflection nebula. It is revealed properly only by photography carried out with the help of a large telescope; at Palomar Observatory in California beautiful colour pictures of it have been taken.

The Hyades. The other important loose or open cluster is that of the Hyades, also in Taurus (the Bull), and extending in a sort of a V-shape from the brilliant red star Aldebaran. Yet Aldebaran is

not a true member of the Hyades cluster; it simply happens to lie in the same direction as seen from Earth, and is roughly halfway between the Hyades and ourselves. On the whole this is rather a pity, because the bright reddish light of Aldebaran tends to overpower the cluster; but in any case the Hyades are less rich, more scattered and less spectacular than the Pleiades, though their individual stars are brighter.

The best views of open clusters of this sort are obtained with binoculars. The field of a telescope is relatively small, and only a small part of the cluster can be viewed at any one moment, so that the main effect is lost. Another beautiful object is the Sword-Handle of Perseus, made up of the clusters H.VI.33 and 34, now to be seen almost at the zenith between Perseus and the W of Cassiopeia. Here there are two rich clusters in the same low-power field.

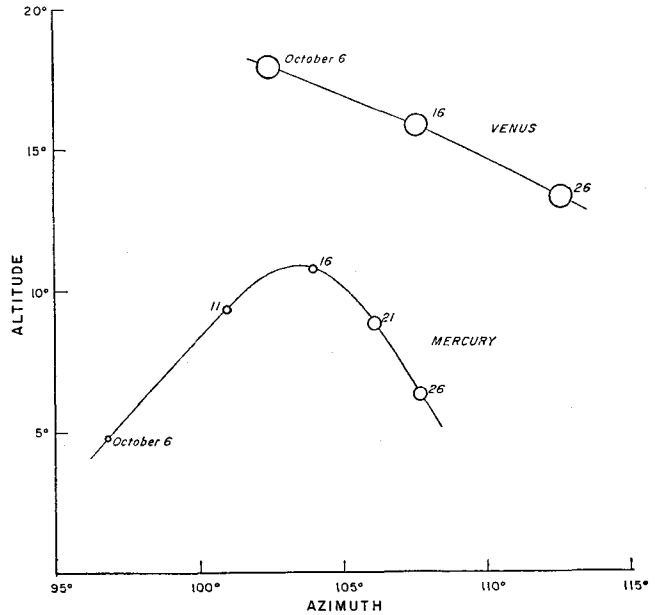
Mira Ceti. Mira, in Cetus (the Whale), is probably the most famous variable star in the sky. At maximum it can rise to well above the third magnitude, though this does not always apply; some maxima are much fainter than others. At minimum, Mira fades down to magnitude 9.

It is at its best during autumn evenings, and this year it will be near maximum at a convenient moment. Its period is 331 days on an average, and this September it should be an easy naked-eye object. A telescope will bring out its red hue; like so many long-period variables, Mira is a Red Giant star.

October

New Moon: October 11 *Full Moon:* October 25

Mercury is at greatest western elongation (morning star) on October 14 (18 degrees), when it is well placed in the east before sunrise. The diagram shows the changes in altitude and azimuth of Mercury on successive mornings when the Sun is 6 degrees below



Mercury and Venus, October 1969

the horizon – about 35 minutes before sunrise at this time of year. The changes in brightness are roughly indicated by the size of the circles; it will be seen that Mercury is much brighter after the date of western elongation. The diagram also shows the positions of Venus at this time; there is no likelihood of confusion, since Venus is so much brighter than Mercury and is also higher in the sky. It

will be noticed that Venus, now moving in towards the Sun, has a retrograde motion.

Venus is still a bright morning star, but there is now less chance of seeing it in a dark sky, since it rises less than two hours before the Sun at the end of the month. In mid-October Venus may be used as a guide to search for Mercury (see note above) which will be found some degrees nearer to the horizon.

Mars moves rapidly through Sagittarius during the month, and continues to set in mid-evening, fading to magnitude +0·4 by the end of October. Mars is at perihelion (nearest to the Sun) on October 21 at a distance from the Sun of 128,000,000 miles.

Jupiter is in conjunction on October 9 and will not be visible, but by the end of the month it rises as a morning star nearly two hours before the Sun. Jupiter is moving direct in Virgo, near the star *Spica*.

Saturn is at opposition on October 29 at a distance of 766,000,000 miles. It reaches a magnitude of +0·1 and since it is north of the equator and the rings are well open, this is quite a favourable opposition. A small telescope will show the rings as well as Saturn's largest satellite, Titan; the south side of the rings is presented to us, and they are tilted at an angle of about 18 degrees. When the rings are fully open the planet may reach magnitude −0·3, and this will occur in a few years' time, when Saturn is in opposition in Taurus.

Titan. Saturn is now at opposition. The rings are well displayed, and this is also a good time to look for some of the members of the planet's system of satellites. Of these, much the largest is Titan, which is only slightly below the 8th magnitude, and is therefore an easy object with a small telescope.

Diameter measures of the satellites of the major planets are always difficult, and the various values given for Titan by different authorities do not agree particularly well; they range from 2,700

miles up to as much as 3,500 miles. If the latter figure is correct, Titan has the distinction of being the largest-known satellite in the Solar System, with Jupiter's Ganymede and Callisto decidedly inferior to it. Titan, then, is of planetary size, and may be larger than Mercury, though not so massive.

Titan has another distinction also; it alone among satellites has a known atmosphere. It is made up chiefly of methane, and is very tenuous, but its existence is not in doubt; it was detected by G. P. Kuiper as long ago as 1944.

The colour of Titan is somewhat yellowish. Surface markings on it can be made out with giant telescopes, but they are of course very difficult indeed, and no instrument of aperture less than 30 inches has any hope of showing them. Because Titan is so large, its shadow can occasionally eclipse the inner satellite; eclipses of this sort have actually been observed, though unfortunately none are due in the near future.

Twelve Years of Space Research. October 4 is the anniversary of the Space Age. On that day in 1957 the Russians launched the first earth satellite, Sputnik I, which may seem very insignificant when compared with later vehicles, but which was of unparalleled importance. Two years later, in October 1959, the Russians sent up Lunik 3, which went round the Moon and sent back the first photographs of the lunar regions which can never be seen from Earth because they are always turned away from us.

Much has happened in these first dozen years of space research. During 1967 and 1968 there were signs that the original impetus had weakened; this was due partly to the tragedies of early 1967, involving first the deaths of three American astronauts during a practice at Cape Kennedy followed soon afterwards by the fatal crash-landing of Colonel Vladimir Komarov in his space-craft, and partly – with the United States programme – to the Vietnam war. By October 1969 there may well have been a fresh series of triumphs. Certainly the American team hopes to put a man on the Moon before 1970, and in view of this it is hardly likely that the Russians will relax their efforts.

Mars at Perihelion. Mars is now badly placed, because it is well south of the celestial equator and because it is a long way from the Earth. Not even large telescopes will show much detail on it, though of course the main features can still be made out. This month it reaches its nearest point to the Sun; and it is worth noting that the Martian orbit is much more eccentric than ours, so that the changing distance from the Sun has a pronounced effect upon the seasons there. As with Earth, the southern summer is shorter and hotter than the northern, while the southern winter is longer and colder. This is shown up by the behaviour of the polar caps. At midsummer in the northern hemisphere of Mars the remnant of the polar cap can still be seen, but the southern cap has been known to vanish entirely; on the other hand, the maximum extent of the southern cap is appreciably greater than that of its northern counterpart. This behaviour would be expected if the caps are composed of some thin layer of icy or frosty substance, as is still the majority view among astronomers – even though the old idea of caps made up of solid carbon dioxide, as suggested by Johnstone Stoney more than half a century ago, has been revived lately in view of the revelations of Mariner IV in the summer of 1965.

November

New Moon: November 9 *Full Moon:* November 23

Mercury is in superior conjunction on November 16 and will not be visible during the month.

Venus now rises less than two hours before the Sun, and will only be seen in the bright dawn sky. It passes half a degree north of Jupiter on November 4, and 4 degrees north of *Spica* on the same morning. Although it should be possible to find the two planets (magnitudes: Venus −3·4, Jupiter −1·2), it will be more difficult to detect *Spica* without optical aid.

Mars may still be seen in the south-west after sunset, setting at about 21^h, moving at the beginning of the month from Sagittarius into Capricornus. By the end of the month, Mars will have faded to magnitude +0·7, and this means that it is only about one-tenth as bright as it was at opposition. In spite of this, it is still brighter than any of the neighbouring stars.

Jupiter may now be seen in a dark sky as a morning star, rising in the east more than two hours before the Sun. The conjunction with Venus on November 4 is referred to in the note above.

Saturn is still the brightest of the evening planets, although it fades a little during the month (magnitude +0·1 to +0·3). It is visible for most of the night, but sets before dawn.

The Twins, and Angular Distances between Stars. Castor and Pollux, the Twins, are now well above the horizon in the late evening. They form a striking pair; Pollux is now the brighter of the two, and is ranked of the first magnitude, while Castor is of magnitude $1\frac{1}{2}$ and is generally excluded from the 'senior' class. However, the astronomers of Classical Greece made Castor the more brilliant, and there have been suggestions that it has faded

during the last 2,000 years. Other stars thought to have faded similarly are Megrez in the Great Bear, Denebola or Beta Leonis, and 'the Last of the River', Acamar or Theta Eridani. It must be admitted that the evidence is far from conclusive, but the possibility is there.

The angular distance between Castor and Pollux is 4½ degrees, so that they appear exceptionally close together even though they are not really associated (Castor is much the more distant of the two). It may be interesting and useful to give a list of the angular distances between some of the other bright stars visible in the northern hemisphere:

Degrees	
4·5	Castor to Pollux
18·6	Rigel to Betelgeux
22·8	Pollux to Procyon
26·5	Rigel to Aldebaran
30·0	Castor to Capella
32·8	Arcturus to Spica
34·2	Vega to Altair
37·0	Pollux to Regulus
38·0	Altair to Deneb
39·5	Capella to Betelgeux
43·2	Castor to Aldebaran
43·4	Polaris to Capella
44·7	Polaris to Deneb
45·9	Antares to Spica
46·0	Sirius to Aldebaran
47·0	Sirius to Pollux
51·1	Capella to Procyon
52·2	Rigel to Castor
54·2	Rigel to Capella
56·0	Antares to Arcturus
59·1	Arcturus to Vega
59·2	Altair to Fomalhaut
59·7	Regulus to Arcturus
60·3	Antares to Altair
61·8	Pollux to Polaris
65·8	Sirius to Capella
71·5	Polaris to Arcturus
71·7	Vega to Antares

Degrees	
72·9	Polaris to Aldebaran.
75·8	Rigel to Regulus
78·3	Polaris to Regulus
80·8	Deneb to Arcturus
81·2	Arcturus to Altair
82·9	Antares to Fomalhaut
84·6	Polaris to Procyon
87·4	Pollux to Arcturus
87·8	Spica to Vega
89·6	Rigel to Fomalhaut
90·8	Pollux to Spica
91·4	Vega to Fomalhaut
91·7	Antares to Deneb

In the far south, the two brilliant stars Alpha and Beta Centauri are separated by 4·5 degrees, equal to the separation between Castor and Pollux.

The November Leonids. Of all meteor showers the Leonids are the most unpredictable – and they can also be the most spectacular. They used to give brilliant displays every 33 years, and there were tremendous showers in, for instance, 1799, 1833 and 1866. Then the path of the main swarm was perturbed by the influences of the giant planets, and there were no major displays in 1899 or 1933. Then, in 1966, the Leonids were back once more – and the display was fully as spectacular as any of those of the past; but unfortunately it took place during daytime in Europe, and so was not visible.

From Arizona and other places, however, the hourly rate apparently reached 100,000. The fact that the maximum was so short showed that the Leonids were condensed into a small area, so that presumably they had been ejected quite recently from their parent comet; and it is interesting to note that this comet, Tempel's, had been recovered as a result of calculations by B. Marsden even though it had long since been given up as lost.

In 1967 the Full Moon lay not far from the radiant at the shower maximum (November 17), but in any case the display was not expected to be bright. The Leonids were similarly unspectacu-

lar in 1968, and there are no grounds for supposing that they will be brilliant in 1969. However, numbers of Leonids are seen every year, and it will be worth watching around the time of maximum – that is to say, after midnight on the early morning of the 17th – particularly as the meteors are bright individually, so that they are comparatively easy to record with an ordinary fixed camera.

December

New Moon: December 9 *Full Moon:* December 23

Solstice: December 22

Mercury is at greatest eastern elongation (evening star) on December 27 (20 degrees), and it may be possible to observe the planet at the end of the year, a few degrees above the horizon in the south-west just after sunset.

Venus rises an hour before the Sun at the beginning of the month, but the planet is moving in towards superior conjunction and is not likely to be seen at the end of the year. Venus will be an evening star for the greater part of 1970.

Mars is still visible as an evening star, in the south at sunset, and setting at about 21^h. Its rapid direct motion carries it into Aquarius in mid-December, and it fades to magnitude $+1{\cdot}0$. The next opposition of Mars takes place in 1971.

Jupiter is a bright morning star (magnitude $-1{\cdot}3$ to $-1{\cdot}5$), moving direct a few degrees to the east of *Spica*. It rises about three hours after midnight, and by the end of the year will be seen in the south just before sunrise. The next opposition of Jupiter takes place in 1970 April, when the planet will be in the same part of Virgo.

Saturn is an evening star, moving direct in Aries, and setting at about the same time as Jupiter rises in the opposite part of the sky. Saturn fades to magnitude $+0{\cdot}5$ by the end of the year, and the next opposition does not occur until 1970 November.

The W of Cassiopeia. The constellation of Cassiopeia is one of the most well-marked in the northern sky, and anyone who has any knowledge of the star-groups will be able to pick out the prominent W. Cassiopeia never sets over Great Britain or the northern United States; during December evenings it is practically overhead.

Of the five W stars, the most interesting is the central member,

Gamma Cassiopeiæ. It is a curious kind of variable, with a spectrum that is aptly described as 'peculiar'. In 1936 it brightened up from its normal magnitude of just below 2, and reached 1·6 before fading again down to as faint as magnitude 3. It then made a recovery, and through much of 1968 it was again of magnitude 2, a little below the Pole Star. Gamma Cassiopeiæ has been classed as a pseudo-nova, and ejects shells of gas; Russian astronomers have stated that a new outburst may be imminent, so that the star is worth watching.

Shedir, or Alpha Cassiopeiæ, is of spectrum K, so that it is decidedly orange. It has long been regarded as irregularly variable within a fairly narrow range ($2\frac{1}{4}$ to $2\frac{3}{4}$); doubts have now been cast on the reality of its variations, but it too is worth watching, and Beta Cassiopeiæ in the W (magnitude 2·3) makes a very convenient comparison.

Close to Beta is Rho Cassiopeiæ, which is definitely variable. Generally it is of about the fifth magnitude, and may be compared with its neighbours Sigma (4·9) and Tau (5·1), but at times it drops to the very limit of naked-eye visibility. The class into which it should be placed is not known, and neither do we know whether it has any semblance of a period. Its changes can be followed with the naked eye, but it is better studied with binoculars, because Sigma and Tau are in the same binocular field.

It was in Cassiopeia, too, that the famous supernova of 1572 appeared. This was Tycho Brahe's star; at its best it became brilliant enough to be seen with the naked eye in broad daylight. Its site is now marked by a radio source, and also in the constellation is another radio source, Cassiopeia A, which is among the strongest in the entire sky. The Milky Way flows through the constellation, and there are many interesting telescopic objects within its boundaries.

The Return of Jupiter. Jupiter is again available for observation, though it is a morning star throughout the month and does not rise until well after midnight. It is not far from Spica, so that it is farther south than it has been for some time. By the end of 1970

it will have passed into Libra, so that British and North American observers will be anxious to make the most of their opportunities during the coming opposition.

Jupiter has an exceptional fascination, because its surface details are always changing. Normally, the North Equatorial Belt is the most conspicuous feature, though at times during 1968 it yielded pride of place to the South Equatorial. The Great Red Spot, which has intrigued observers for so many decades, is very much in evidence, together with its well-marked Hollow; the colour is easy to see even with a modest telescope.

The Active Sun. On December 22 the Sun reaches its southernmost point in the sky. Nevertheless, solar observers will be studying it as intensively as possible, because this is a time when great activity is to be expected, and there should be many large groups of sunspots; the maximum of the solar cycle, due in 1969, is a long-drawn-out affair. In addition to the interest of the sunspots and associated solar phenomena, there is always the chance of spectacular auroræ, and these at least are most likely to be seen during the long nights of winter. Auroræ are described in the article by H. G. Miles in the present *Yearbook*; in this field of research the naked-eye observer comes into his own – particularly if he lives in a comparatively high latitude, from which auroræ are common. As the Sun's activity decreases, as it will certainly do in the early 1970s, brilliant displays will become less frequent until the solar cycle starts to increase once more to its next maximum around 1980.

Eclipses, 1969

In 1969 there are two eclipses; this is the smallest number that can occur in any one year, and both are annular eclipses of the Sun. There are also three penumbral eclipses of the Moon.

1. *An annular eclipse of the Sun* on March 18 of short duration, the track passing from the Indian Ocean across Indonesia to end in the Pacific Ocean. There will be a partial eclipse in Australia, reaching its greatest magnitude in the north and west.
2. *A penumbral eclipse of the Moon* on April 2, the end of which will be visible in Europe. Central eclipse (73 per cent) occurs at $18^h\ 33^m$ G.M.T., roughly the time of moonrise in southern England.
3. *A penumbral eclipse of the Moon* on August 27 of very small magnitude – only about 4 per cent.
4. *An annular eclipse of the Sun* on September 11, with a maximum duration of more than three minutes. The track runs from the North Pacific Ocean in a south-easterly direction to end in South America. It will be visible as a partial eclipse in all but the north-eastern parts of the U.S.A. and Canada, the greatest magnitude being observed near the western seaboard.
5. *A penumbral eclipse of the Moon* of large magnitude (93 per cent) on September 25, generally visible in the British Isles. Central eclipse occurs at $20^h\ 10^m$ G.M.T.

Occultations

In the course of its journey round the sky each month, the Moon passes in front of all the stars in its path, and the timing of these occultations is useful in fixing the position and motion of the Moon. The Moon's orbit is tilted at more than 5 degrees to the

ecliptic, but it is not fixed in space. It twists steadily westwards at a rate of about 20 degrees a year, a complete revolution taking 18·6 years, during which time all the stars that lie within about $6\frac{1}{2}$ degrees of the ecliptic will be occulted. The occultations of any one star continue month after month until the Moon's path has twisted away from the star, but only a few of these occultations will be visible at any one place in hours of darkness.

There are only four first-magnitude stars that can be occulted by the Moon; these are *Regulus*, *Aldebaran*, *Spica* and *Antares*. In 1969 occultations of *Spica* and *Antares* continue throughout the year, but none of these is visible in the British Isles; the occultation of *Spica* in the early morning of March 7 is, however, visible in parts of America. In December a series of occultations of *Regulus* will begin, that of December 28 being visible in North America. The planets Mercury, Venus, Mars and Uranus will all be occulted during the year, but observations will not be possible in this country or the western hemisphere.

Details of occultations of the planets, and of all stars down to magnitude 7·5, as well as possible occultations of stars by planets, are published in the annual *Handbook* of the British Astronomical Association. Similar information applicable to North America is given in the monthly journal *Sky and Telescope*.

Comets in 1969

The appearance of a bright comet is a rare event which can never be predicted in advance, because this class of object travels round the Sun in an enormous orbit with a period which may well be many thousands of years. There are therefore no previous records of the previous appearance of these bodies, and we are unable to follow their wanderings through space. The comets of short period, on the other hand, return at regular intervals, and attract a good deal of attention from astronomers. Unfortunately they are all faint objects, and are recovered and followed by photographic methods using large telescopes. Most of these short-period comets

travel in orbits of small inclination which reach out to the orbit of Jupiter, and it is this planet which is mainly responsible for the severe perturbations which many of these comets undergo. Unlike the planets, comets may be seen in any part of the sky, but since their distances from the earth are similar to those of the planets their apparent movements in the sky are also somewhat similar, and some of them may be followed for long periods of time.

In 1969 the following short-period comets are expected to be recovered:

Comet Honda-Mrkos-Pajdusakova was last seen under poor conditions in 1964. It was discovered in 1948 and has the very short period of 5·2 years.

Comet Harrington-Abell was discovered at Mount Palomar in 1955 and was again seen in 1962. It is a very faint object, although its distances from the Sun and Earth are not unduly large. This comet has a period of 7·2 years.

Comet Faye is one of the better known comets, and has made 15 returns to the Sun since its discovery in 1843. Its orbit, which has a period of 7·4 years, does not change very much.

Comet Comas Solá is a brighter object than any of the others mentioned, and on its last return in 1960 it was followed for nearly two years. Discovered in 1926, it has been observed at five returns and has a period of 8·6 years.

Comet Schwassmann-Wachmann (1) has a nearly circular orbit lying entirely between the orbits of Jupiter and Saturn. It behaves very much like a planet and is visible every year. This comet, which has a period of 16 years, is remarkable because it undergoes changes of brightness, which seem to have some connection with solar activity.

Meteors

Meteors ('shooting stars') may be seen on any clear moonless night, but on certain nights of the year their number increases noticeably. This occurs when the Earth chances to intersect the

orbit of a meteor swarm, which is a concentration of meteoric dust moving in an orbit around the Sun. Such an intersection can occur only at one particular time of year, but if the dust is spread out along the orbit, the resulting shower of meteors may last for several days. The word 'shower' must not be misinterpreted – only on very rare occasions have the meteors fallen so fast as to resemble snowflakes falling.

The naked-eye study of meteors is quite a laborious task, but even a casual observer, watching for, say, ten minutes on an August night, may observe a number of Perseids. If their tracks are marked on a star map, and traced backwards, a number of them will be found to intersect in a point (or a small area of the sky) which marks the radiant of the shower. This gives the direction from which the meteors have come.

The following table gives some of the more easily observed showers, with their radiants; the effect of moonlight in 1969 is indicated.

Limiting dates	*Shower*	*Maximum*	*R.A.*	*Dec.*	*Notes*
Jan. 3–4	Quadrantids	Jan. 3	$15^h\ 28^m$	$+50°$	M
April 20–22	Lyrids	April 22	$18^h\ 04^m$	$+33°$	
July 27–Aug. 17	Perseids	Aug. 12	$3^h\ 04^m$	$+58°$	
Oct. 15–25	Orionids	Oct. 20–21	$6^h\ 24^m$	$+15°$	
Oct. 26–Nov. 16	Taurids	Nov. 1–7	$3^h\ 36^m$	$+14°$	
Nov. 15–17	Leonids	Nov. 16	$10^h\ 08^m$	$+22°$	
Dec. 9–14	Geminids	Dec. 13	$7^h\ 28^m$	$+32°$	
Dec. 20–22	Ursids	Dec. 22	$14^h\ 28^m$	$+76°$	M

M = moonlight interferes

Minor Planets, 1969

Nearly 2,000 minor planets are listed in the catalogues, but of these only the 'big four', Ceres, Pallas, Juno and Vesta, can reach any considerable brightness, and only the last of these, Vesta, can

occasionally be seen with the naked eye. In 1969, however, there is no opposition of Vesta, and it only reaches magnitude +6·7 at the end of the year. The other three are even fainter, the magnitudes at the time of opposition being Ceres +7·2 on July 27; Pallas +9·1 on June 25; Juno +9·6 on June 30.

Some Events of 1970

ECLIPSES

In 1970 there will be four eclipses, two of the Sun and two of the Moon.

February 21 – a partial eclipse of the Moon, visible in the Americas and Australasia.

March 7 – a total eclipse of the Sun, the central track crossing central America from the Pacific to the North Atlantic oceans.

August 17 – a partial eclipse of the Moon, visible in Europe, Africa and America.

August 31 – an annular eclipse of the Sun, visible only in Australasia and the Pacific Ocean.

THE PLANETS

Mercury will be well placed at eastern elongation as an evening star on April 18, and as a morning star at western elongation on September 28.

There is a *Transit of Mercury* across the face of the Sun on May 9, generally visible in Great Britain, Europe, Africa, Asia and Australia.

Venus will be an evening star after superior conjunction on January 24, greatest eastern elongation occurring on September 1. After inferior conjunction on November 10, Venus will be a morning star.

Mars is in conjunction on August 2, and will not be very conspicuous during the year; it will be an evening star before conjunction and a morning star for the rest of the year.

Jupiter will be at opposition on April 21 in Virgo.

Saturn will be at opposition on the borders of Aries-Taurus on November 11.

Uranus is in Virgo and comes to opposition on March 27.

Neptune will be at opposition on May 21 in Libra.

Pluto remains on the borders of Coma-Virgo and reaches opposition on March 17.

PART TWO

Article Section

Once again we have a varied selection of articles, ranging from our near neighbours in the Solar System out to the Galaxy and beyond. It is hoped that there will be 'something for everybody', from the beginner to the serious student of astronomical science.

Infrared Astronomy

D. A. ALLEN

From the earliest days when primitive man began his study of the stars and planets, and astronomy was founded, he has been primarily concerned with the light he received through the Earth's atmosphere. Having ideally suited detectors of electromagnetic radiation of such wavelengths – namely eyes – it is not surprising that he could readily assemble the data, and for several thousand years the science of astronomy consisted merely of collating and interpreting the information so acquired.

The individual techniques varied – and the analysis of spectra shows the most marked deviation – but in all cases astronomers were dealing with radiation of a very restricted wavelength range, from about 4,000 to 7,000 Ångströms to be precise.

Thus it was with much surprise and subsequent jubilation that early in the 1930s emission was discovered in the radio region of the spectrum by a radiometeorologist, Karl Jansky. At 20·5 Mc/s (14·6 metres) he succeeded in detecting and identifying radio signals from the centre of our galaxy.

The repercussions of this discovery were as immense as when man first saw the stars creeping into view shortly after dusk, and wondered. . . . In only thirty years, radio astronomy has proved itself to be one of the major tools in probing the mysteries of the universe. In particular the past ten years have seen radio and optical astronomers working hand in hand, and providing more information, more problems and more solutions than ever before in the history of astronomy.

But electromagnetic radiation is not confined to two narrow wavebands, and extends over an unlimited range (see Fig. 1). Why, then, can we not detect external radiation of other wavelengths?

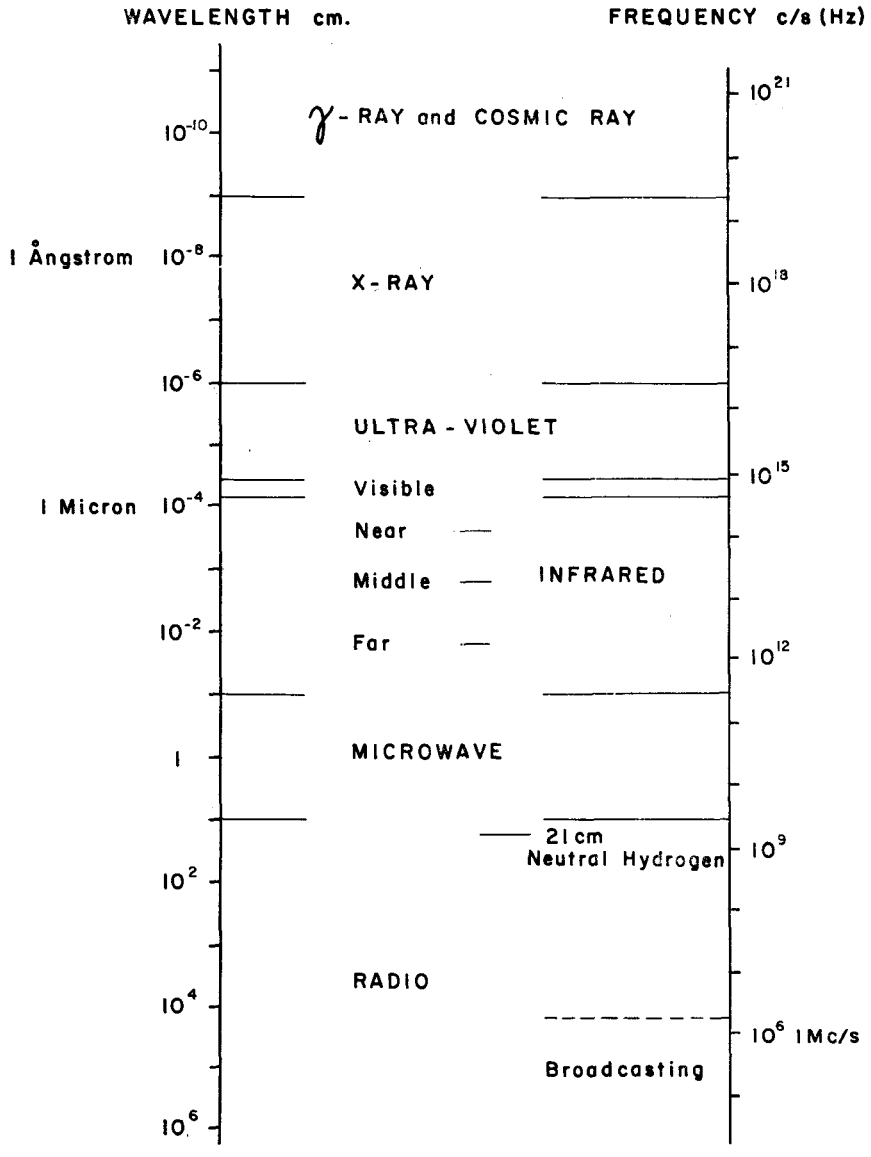


Fig. 1 The Electromagnetic Spectrum

The answer, of course, lies in that vast mantle of gas, dust and plasma, the atmosphere. Radiation of intermediate wavelengths is almost totally reflected, scattered or absorbed by various constituents of the atmosphere within a few centimetres' travel. Until recently it was believed that the only wavebands permitting relatively unhindered passage of radiation through the atmosphere were the optical and radio 'windows'. The restrictions were quite critical. Thus, for instance, only a small fraction of light beyond the violet end of the spectrum is transmitted, and this ultraviolet is responsible for sunburn, particularly in mountainous regions where the atmosphere is thinner.

As long ago as the 18th century Sir William Herschel, noticing that the sun emitted heat, wondered which colours of the rainbow had associated with them the warmth he felt. To investigate this he dispersed sunlight through a prism and mounted thermometers with their bulbs in the light beams of differing colours. As a reference, Herschel placed one thermometer beyond the red end, and to his immense surprise it was this instrument which rose quickest in temperature. He had discovered a new type of ray – heat rays – of longer wavelength than red light, and transmitted, or partially transmitted at any rate, by the atmosphere.

Over the last century, the electromagnetic spectrum has been studied and analysed by physicists. It was subdivided into regions as shown in Figure 1, and in particular the name *infrared* was given to the vast, amorphous chunk between red light at 7,000 Ångströms and microwaves at 1 mm wavelength. Divisions into near-, middle- and far-infrared are somewhat arbitrary.

Here lies a strange jungle domain indeed, a land where wavelengths are counted in microns* and one measures not light but heat – a world in which a suitable detector can 'see' in the dark – a place where black objects are 'brighter' than white ones and where a house or a mouse sticks out like a sore thumb against the darker background. The sky is always dusky, save near to the Sun, the brightest object of all.

* micron (μ)=10,000 Ångströms; 1 mm=1,000μ. Thus visible haslight wavelengths of about $\frac{1}{2}\mu$.

The physicists worked feverishly to build detectors capable of exploring the wilder recesses of the electromagnetic spectrum, but practically the last to fall under their machetes was the infrared. As they cleared away the forest and the light of day broke through, what a fascinating new world was revealed. To their dismay, perhaps inevitably, they found that Nature had been there before them and equipped certain animals, e.g. the Pit Viper, with infrared sensitive 'vision' enabling them to detect their prey by night. But now man was there.

The first people to populate this new haven were the spectroscopists, who found numerous absorption lines and bands for them to get their teeth into. Molecular spectroscopy became the 'in' science and progressed by leaps and bounds, while all the time the physicists were hacking back the undergrowth: 10 microns, 100 microns . . .

One of the earliest, and still the best, of the non-selective detectors is the Golay cell, named after its inventor. The principle, crude but effective, is shown in Figure 2. Incoming radiation warms up the cylinder of gas, which on expanding bows out the diaphragm causing the mirror to tip. The deflection of the light beam is optically magnified to a measurable quantity. Such a device is sensitive to an incoming power of 10^{-11} watts – about the signal from a human hand at ten miles – but more sensitive detectors were needed.

The last decade has seen an increase in the number of such devices suitable for these wavelengths. At first the so-called photovoltaic detectors spanned the region up to a few microns. These are similar to the Cadmium Sulphide in exposure meters, and produce a small voltage when radiation is incident upon them. All such detectors have a sharp upper limit of detectable wavelength, and usually only function favourably within a narrow waveband. For longer wavelengths photoconductive detectors are used. Such instruments comprise carefully purified semiconductor (usually germanium) crystals 'doped' with an impurity such as gold or copper. As their name implies, they change their resistance under incident radiation. The signal produced is very weak, and extremely

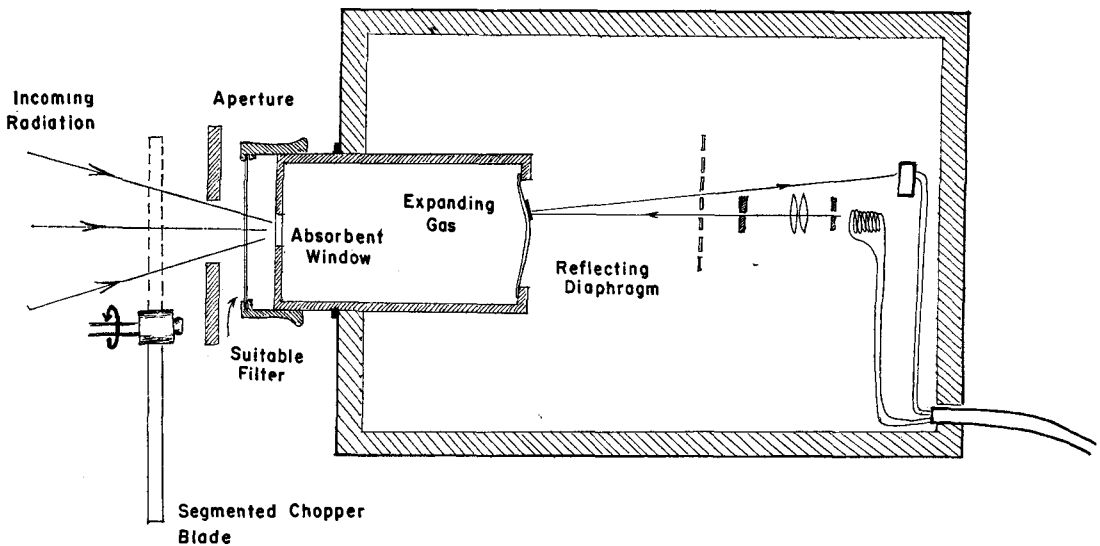


Fig. 2. The principle of the Golay Cell. Incident radiation is square-wave modulated at 10 c/s, and passes through a filter selecting the required waveband, where it is absorbed by the cylinder of gas. The expanding diaphragm gives a deflection in the light beam.

high-gain/low-impedance amplifiers are needed. The incoming radiation is usually modulated, or chopped, by means of a rotating blade in front of the detector; this eliminates drift in the semiconductor signal and provides an alternating output suitable for amplification by valve or transistor.

Just to add to the troubles of making and using such detectors, they must be cooled during use. And it's no good putting them in a fridge – even short-wavelength detectors require liquid nitrogen cooling (to 77°K), while the photoconductive set generally refuse to work at temperatures much above that of liquid helium (4·2°K). Some need to be even cooler.

All infrared detectors are limited in sensitivity by noise, and in the extreme case this comes from the background at ambient temperature against which the detector must see its target; for rather complex theoretical reasons this sets a limit on the sensitivity of any detector. The limit for a 10-μ detector is about 10^{-15} watts under ideal conditions. Practical detectors approach this limit quite closely.

Such detectors were soon employed in military applications, where their ability to detect warm bodies by night was of extreme tactical importance, and in aerial photography. It rapidly became clear that only certain wavebands were transmitted through even short atmospheric paths. For where the spectroscopist rejoiced at the absorption bands of di- and tri-atomic molecules, the military poured imprecations upon the atmospheric gases which proved so effective a blanket. They found certain windows and exploited these to their fullest. This hint of transparent – or at least not entirely opaque – windows attracted astronomers who soon began turning these detectors skywards. They found that in the higher atmosphere additional gases, such as ozone, existed to cut down the available radiation yet further. Nonetheless certain regions of the spectrum were transmitted, none perfectly, as shown in Figure 3. The principal absorber is the omnipresent water vapour, but CO_2 provides little relief. Observing from sea level the windows are murky, but 10,000 feet up there is less water vapour and the infrared sky is clearer. Consequently the hill-top observatories

of the United States were soon populated by astronomers with detectors anxious to see what could be seen.

They used some of the windows around 1μ at first, but the 1-micron sky turned out to differ little from that at optical wavelengths. At $2{\cdot}2\mu$ things began to look rather different; similarly at 5μ. But the clearest window of all is the 8–14-micron region, and it is here that most results have been obtained. Some workers have successfully exploited the $17–25\mu$ window, and other very much longer wavelengths, approaching microwave.

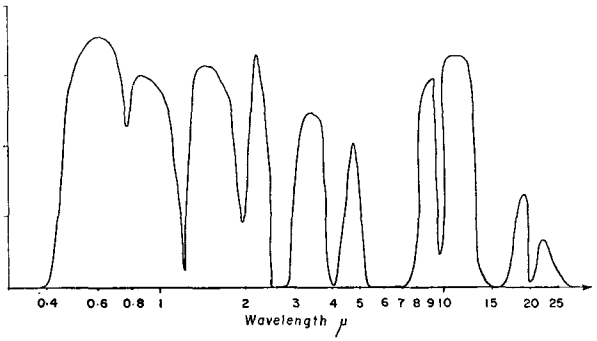


Fig. 3. The infrared and optical atmospheric windows. Transmission is plotted against wavelength in microns. The visible window is at extreme left, and the 17–25μ window on the right.

In the 8–14-micron window, bodies at room temperature emit their greatest energy. This includes the sky, telescope, mirrors, etc., as well as anything else that gets into the field of view. Discriminating the incoming signal is by no means easy, and has been likened to observing stars by day using a luminous telescope. Reflectors must be used as the glass of an objective does not transmit these wavelengths at all, and lenses of pure germanium or sapphire are prohibitively expensive!

Infrared astronomy is primarily concerned with the heat given out by a body, and hence its temperature, and in fact the temperature of some celestial bodies, was first determined by means of the thermocouple some decades ago. Lord Rosse deduced the tempera-

ture of the full moon to be about 400°K, a remarkably accurate result when it is considered that Stefan had not then formulated his black-body law. In the 1920s Pettit and Nicholson measured temperatures on the Moon by day and night, and during eclipse, and of several planets.

But with the more sensitive detectors of the present day, far more can be discovered at these wavelengths. Indeed almost any class of object visible to the naked eye has now been seen in the infrared, and most have provided astronomers with some unanticipated aspect.

Not unnaturally the first object observed was the brightest – the Sun. Indeed one scarcely needs an infrared detector to observe heat from that source. At these wavelengths the surface is remarkably uniform and uninteresting. Sunspots are barely noticed, while the darkening of the limb so obvious at optical wavelengths no longer exists. The Sun is merely a big hot blob in the sky, and is really more of a nuisance than anything else. Not even the extremely hot corona emits much at these wavelengths, being too tenuous. But some distance beyond, the dust of the Zodiacal Light is heated to a temperature of several thousand degrees, and though there isn't much of it, it is a very efficient emitter and can be observed for some distance from the Sun. No really accurate results have yet been obtained from this source.

When the Sun proves uninteresting, the next object one thinks of is the Moon. Early work on our satellite involved measuring its temperature variations through a lunation, and it was found to have not only an extreme range (+120°C to −160°C), but also to warm up and cool down much faster than any known terrestrial rocks. This gives some clue to the nature of the Moon's surface, but has not yet been fully explained.

While scanning the eclipsed Moon in 1959, Shorthill and Saari discovered that the crater Aristarchus cooled slower than the rest of the Moon. Subsequent observations both by Shorthill and Saari and by other workers have revealed that during eclipse and after lunar sunset not only do Aristarchus and other bright-ray craters such as Tycho and Copernicus remain hot, but several hundred

other 'hot spots' occur. Many of these have been identified with smaller craters, some with bright patches, but others are as yet uncorrelated with any known selenographic formations. The cause of these thermal anomalies is unknown; perhaps changes in the density or thermal conductivity of the surface rocks might account for them, or local surface irregularities on a small scale. Internal sources of heat certainly do not explain the larger anomalies, but could possibly be invoked to explain the smaller ones. The Hyginus Cleft, for instance, is a well-known hot spot.

The illuminated Moon, too, has been scanned in the 8–14μ region. At these wavelengths it is seen by its own thermal emission and not by reflected sunlight. Craters stand out much more clearly near full moon than their optical counterparts: one wall has been longer in sunlight and is therefore warmer than the other. Many of the thermally anomalous craters appear slightly cooler, showing that they are also slow to warm up.

Spectral analysis of the radiation from the Moon yields some data on its composition. This is a difficult field, and one in which much remains to be done, especially as the nature of the spectrum depends on the surface microstructure. When these problems are more fully understood, this technique will provide a powerful method of compositional study on a scale that spacecraft and astronauts could not hope to match for generations to come.

The planets, too, have had their temperatures taken by this remote means, though the outer four are too cool to give very accurate results. Venus has a fairly uniform temperature of about 210°K, and is frequently hottest on the side away from the Sun, suggesting a fairly rapid rotation. The Galilean satellites of Jupiter also provide measurable signals, and have temperatures around −120°C.

Spectral work has yielded information on the atmospheric composition of some planets, notably Mars, though it is difficult for ground-based observers to accurately allow for the Earth's intervening atmospheric gases. CO_2 in the Martian atmosphere was confirmed by this technique.

In the line of surprises, Venus first turned up with thermal anomalies. The resolution on Venus is clearly much poorer than on the Moon, but at that distance a source such as Tycho would be detectable. In the same way locally warm areas have been found on more than one occasion near the southern cusp of the planet. Unlike the Moon's hot spots, the Cytherean anomalies seem to persist irrespective of whether the Sun is shining locally, and suggest some internal source. It would be pointless to speculate on their possible origins at this early stage.

While scanning Jupiter in 1964, a small area of quite intense radiation was found coincident with the shadow of one of the satellites. Subsequent observations that opposition showed this phenomenon every time a satellite shadow transited. Exactly why such a shadow should be so hot is a complete mystery, but even more curious is the total disappearance of this phenomenon in 1965 and 1966. Yet the original observations remain well substantiated.

Outside the Solar System, the first objects one hopes to be able to see are stars. Radio astronomers, of course, are still searching for a true radio star, but at infrared wavelengths the situation is far simpler. All visible stars must emit infrared radiation, and several hundred will give out enough to be picked up by present instrumentation. The brightest star of all at 8–14μ is Betelgeux, with χ Cygni closely following. Both these, together with most other bright infrared stars, are very cool red giants, and are known to vary in their optical light output. Stars of very high temperature emit most of their energy at visible wavelengths, and relatively little in the infrared. The cooler the star, the greater the ratio of infrared to visible brightness. Many cool red stars are known or suspected variables, and one immediate question is: do such stars vary in the infrared? As yet insufficient observations have been made, but it is clear that what infrared variability is present is very small. χ Cygni varies optically by about 11 magnitudes, but by less than one magnitude at 10μ.

A few hot blue stars have been observed, and it seems likely, though not certain, that two are brighter in 8–14μ microns than

would be expected. These two are Regulus (α Leonis) and Bellatrix (γ Orionis), and one interpretation is a cloud of hot dust around each star.

It seems intuitively reasonable to expect some stars to be much cooler than Betelgeux, so cool in fact that they are invisible at optical wavelengths, but could be picked up in the infrared. Neugebauer, Martz and Leighton instigated a search for such sources at 2·2μ. They have published to date a list of seventeen, and all have been examined at longer wavelengths. One, NML Cygnus, is the third-brightest infrared star at 10μ, and has a surface temperature of 500°C, much cooler than the previous coolest-known star.

Travelling farther afield, many galaxies are believed to have strong infrared emission from their nuclei, and indeed our own Galaxy has been found to possess an extremely intense source at its centre. Unfortunately most galaxies are just too weak emitters to measure with present detectors.

Not all infrared sources are thermal, however, and a few emit by synchrotron radiation. Quasars are expected to be very bright in the infrared. Unfortunately at these distances they are difficult to observe satisfactorily, and only 3C-273 has been measured. A watch for variability has begun.

The infrared brightness of planetary nebulæ was estimated to be too low for present detectors. However an emission line of neon should be present at 12·8μ, and it was thought this may be observable. Consequently the ever-hungry germanium detectors were turned in this direction and, to the surprise of all, strong emission was found at 8–14 microns. By filtering out 12·8μ, this was shown not to be due to neon but to be a continuum from the nebular regions. This low-temperature source in planetary nebulæ has not yet been adequately explained.

On the strength of these observations, the Orion nebula, M.42, was scanned at 8–14μ, and 17–25μ. In the former window a point source was located which may well be a star in formation, though it seems to correspond to radio OH emission; the longer waveband revealed an extended source a few minutes of arc across. No optical

identification has been made, but it seems that the source originates within the nebula, and has a temperature of about 70°K. It is, in fact, the brightest object aside from the Sun and Moon at this wavelength, yet is invisible through any other window.

In 1965, Comet Ikeya-Seki passed very close to the Sun and gave a fine display for Southern hemisphere observers. In the north it was much less impressive, and hardly seen at all. From the United States, however, it was successfully tracked in the daylight sky by infrared. No startling results emerged.

Another possible source of radiation would be meteor tracks in the atmosphere. Professional astronomers do not yet appear to have looked for these, and there are certain problems in covering a sufficient area of sky, but no doubt such observations will be made in due course.

The 8–14-micron window comprises wavelengths twenty times greater than optical. Used in conjunction with reflecting telescopes, the implications are twofold: firstly the optics become perfect, i.e. there are no surface irregularities even $\lambda/20$ high and the instrument is diffraction limited; secondly this diffraction limit is twenty times greater. The resolving power is twenty times poorer, and even the 200-inch which was employed for some planetary studies resolves no better than a good 10-inch optically. Most observations have been made with telescopes in the range 20- to 60-inch diameter, and such instruments would not be capable of splitting ϵ Boötis in the infrared, even were the companion star bright enough to be seen.

To make accurate measurements, what is needed, of course, is a larger telescope – one which would give better resolution and greater light grasp. Plans have been suggested for the construction of a 1,000-inch telescope, but though the optical and mechanical tolerances are twenty times less than for an equivalent visual telescope, this would still be a tremendously difficult achievement, and is unlikely to be undertaken for some decades. Nonetheless a few standard-sized infrared telescopes should, and no doubt will be built for continuous day and night observation.

For observations at other infrared wavelengths, it is necessary

to rise above the Earth's atmosphere, and already some balloon flights have been made. But this is both a difficult and expensive business. Looking further ahead, a base on the Moon would solve all these problems.

Reber, the first person to make systematic radio observations, was an amateur, and since his time thousands more amateurs have built and operated their own radio telescopes. Though their instruments are of modest aperture, compared to some of the giant structures now used professionally, they have found much of interest to observe, and have been able to contribute significantly in fields to which the professional can devote little of his time.

When the infrared field becomes wider known, it too will offer a challenge to the amateur. Such work as long period variables could be undertaken at these wavelengths on a scale which the professional may never match. But such work is fraught with difficulties. The simple Golay cell is too insensitive for such work. Semiconductor devices could not be made at home, and would have to be bought. Most amateurs will not have access to liquid helium supplies, though shortly a nitrogen-cooled detector for the 8–14μ window will be available. The amplifier could not be simply made. The apparatus could not be made sufficiently portable for mounting at the Newtonian focus of a telescope. These and many minor problems would enable only the very wealthy and extremely persevering amateur to win through. For any not put off by these comments, and still keen to undertake such work, it should be pointed out that a minimum capital outlay of about £3,000 would at present be needed, and that a 12-hour supply of liquid helium costs about £5. But the rewards of building and operating a satisfactory piece of equipment would doubtless be great.

For the professional the future lies open. We are on the brink of developing a new and exciting aspect of astronomical research – one which could prove as valuable and important as radio astronomy, but one which unlike its sister X-ray astronomy can be carried out from the ground at consequently much lower cost and greater convenience. At the time of writing (February 1968) discoveries are being made monthly, if not weekly, and improvements

are being made to existing detectors, while all the time new windows at longer wavelengths are being explored. Even though as yet there are fewer objects in the sky to study than can be seen by the unaided eye, infrared astronomy has made great strides. Some day, inevitably, a breakthrough will come about in detector design and much fainter sources will be observable. When that day comes, infrared astronomy will blossom forth into the importance it deserves. Even now it must not be underrated.

Only a century ago astronomers believed that their science was virtually complete; all that remained, they thought, was the accurate measurement of star positions and the like! We have learnt not to make sweeping statements on such matters – but who knows what the next century will bring us? In this field, at least, the future looks decidedly rosy.

The Rotation of Mercury

V. A. FIRSOFF

Mercury and Pluto are the naughty boys of the solar family. All the other major planets walk in a nice 'crocodile', keeping close to the Invariable Plane, with which the ecliptic, or the Earth's orbital plane, makes an angle of 1° 34′ 59″, in orbits close to circular, so as not to jostle their neighbours. But the innermost and the outermost known solar planet have little respect for such rules of behaviour and jaywalk anyhow: the inclination of Pluto's orbit to the ecliptic is over 17° and that of Mercury exceeds 7°, and their respective eccentricities are 0·2460 and 0·2056. The two deviants have some other oddities in common, for all of which there exists so far no wholly satisfactory explanation.

They are also difficult to observe and measure: Pluto because it is too far from and Mercury because it is too close to the Sun. Pluto creeps sluggishly at about 3 miles a second along its wide circuit; while Mercury, the quicksilver of the sky, makes from 24·4 to 36·5 miles a second, and returns to the same angular position relatively to the Sun after a mean lapse of 116 days. This is the shortest synodic period for any planet, but it varies considerably because of the high orbital eccentricity.

The mean semi-diameter of Mercury's orbit is 35,950,000 miles, but it is fully 14,800,000 miles nearer the Sun's centre at perihelion than at aphelion, owing to which its maximum apparent angular distance from it, or elongation, at morning and evening apparitions may be anything from 17° 50′ to 27° 5′. At most times Mercury is lost in sunglare, and when it chooses to reveal itself to the naked eye near the horizon for two or three hours at most, its view is unsteady and often marred by mists and clouds. This is especially

so to observers at high geographical latitudes, and Copernicus is said never to have been able to see Mercury at all.

Roger Bacon having narrowly missed inventing the telescope in the thirteenth century, Copernicus had to make do with an astrolabe, but Lippershey and Galileo's 'optick tube' did not improve the position much so far as Mercury was concerned, though it did show its phases. The advent of the Newtonian reflector later on in the seventeenth century made more effective observation possible. Yet even to a telescopic student Mercury is a difficult object. True, its daytime observation, when it can be seen comparatively high in the sky and untroubled by atmospheric unsteadiness, presents no serious problem to an instrument equipped with setting circles and clock drive. Such refinements, however, were slow in coming.

The true diameter of the planet is subject to some uncertainty, but is commonly given as 3,100 miles (2,900 miles according to Müller and Camichel), and subtends at a mean inferior conjunction, when the planet is 50,000,000 miles or so away, an angle of 11″. At such times Mercury is, of course, more or less invisible, bar a transit or a thin sliver of a polar crescent when high above or low below the Sun. Thus its best telescopic views correspond to those of Mars at an unfavourable opposition, with the additional difference that Mercury is then seen as a narrow crescent.

The planet is thinly atmosphered and shows firm surface detail, from which the axial period could, in theory, be readily determined. E. E. Barnard records having occasionally seen the maria of Mercury as dark and clear as Sinus Sabæus and Syrtis Major on Mars, but this is rather exceptional, and as a rule they can be only somewhat uncertainly glimpsed. Indeed, the simultaneous drawings of the planet, even when executed by skilled observers with good equipment, show at best a rudimentary degree of agreement.

The situation is further complicated by librations. The rate of axial spin is substantially uniform and subject only to very minor irregularities, but, as we have seen, Mercury moves nearly a half again as fast at perihelion as it does at aphelion. This causes it to

wobble from side to side, or librate longitudinally, about a mean position as seen from the Sun. This wobble amounts to 23° 42′ both ways, or 47° 24′ all told. In fact, there is a theorem whereby a secondary in synchronous rotation (axial period = orbital period) moving in an elliptical orbit preserves a constant orientation towards the vacant focus of the ellipse.

It must be stressed that longitudinal libration will be there whatever the axial period: it will only become climatically unimportant if this period is short. The first part of this proposition is also true of any latitudinal libration that may arise from the inclination of the polar axis to the normal to the orbital plane. Our seasons and climatic zones are the result of precisely such a libration in latitude.

Add to this the atmospheric veils and obscurations, reported on Mercury by Antoniadi and some other observers, and it is hardly surprising that the early telescopic students of the planet proved unable to cope with the problem of its axial period. Their efforts were based on little more than guesswork. Reasonably enough the guiding idea was that all terrestrial planets ought to rotate similarly to the Earth and Mars in a period of about 24 hours on axes of comparable inclination. This led Johann Schröter in the early nineteenth century to believe that Mercury turned once round in 24 hours and 50 minutes about an axis 20° off the normal.

Much of what is known about the surface features of Mercury is due to the sustained work of two excellent observers in the second half of the nineteenth and the early decades of the twentieth century: G. V. Schiaparelli in Italy and E.-M. Antoniadi in France. They enjoyed good atmospheric conditions. Schiaparelli's aperture was 19·3 inches, which is very respectable for a refractor. Antoniadi had the great 33-inch refractor at Meudon, Paris, at his disposal, and this remains one of the best instruments in the world, second in size in its class only to the 40-inch Yerkes refractor and the 36-inch Lick refractor in the U.S.A. There can be no doubt at all about their skill and accuracy in both observation and preparation of the drawings.

After years of systematic work they both concluded that the

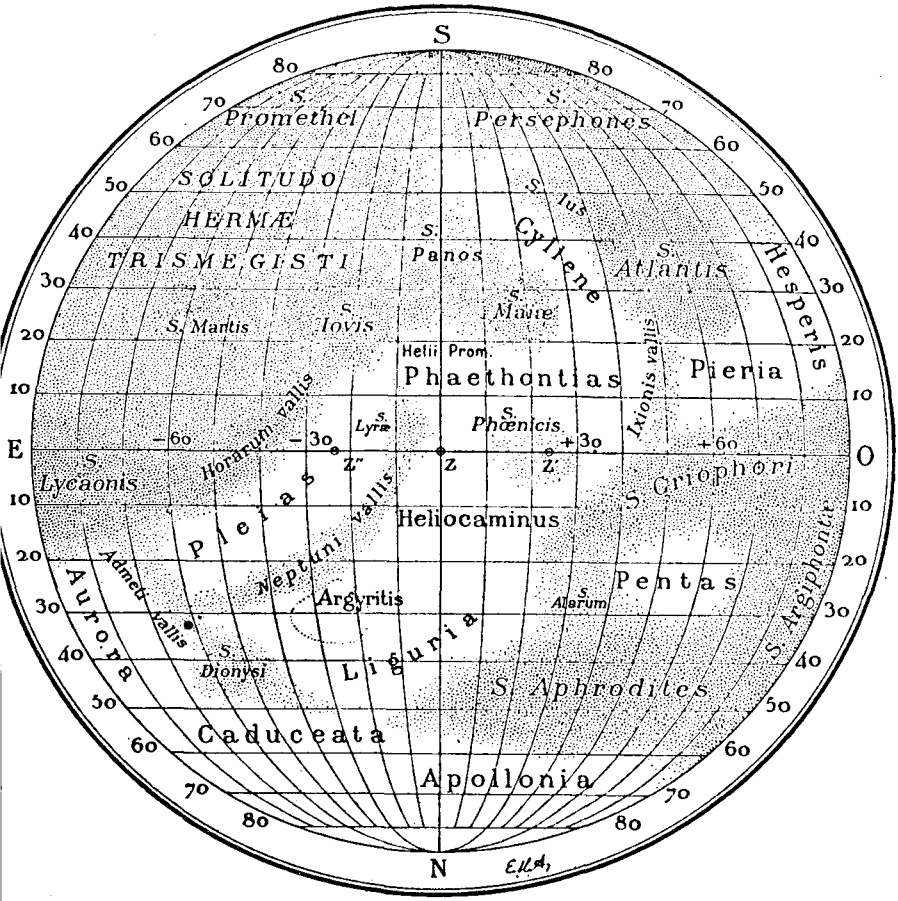
strong body tides raised in Mercury by the variable pull of the close Sun had brought the axial and orbital periods into coinci dence at 88 days (87·969 if you are a stickler for precision). The planet would thus behave towards the Sun in much the same way as the Moon does towards the Earth, one hemisphere being perpetually exposed to scorching heat and the other plunged in eternal night, and the Sun rising and setting only within the wide libration zones. The inclination of the polar axis appeared to be inappreciable and was tentatively put by Antoniadi at 7°.

These opinions carried great weight, and seemed to be fully corroborated by the reappearance of the same features, a 'figure-of-five' marking on the west side and three oblique dusky bands on the east, at successive apparitions. Antoniadi prepared a detailed planisphere of the Sunward side (Fig. 1), showing the maria and terræ of Mercury, which was in good agreement with the similar maps drawn by Schiaparelli and other observers.

Thus it came to be regarded as an established fact that Mercury had a synchronous period of rotation. Nevertheless, some doubts persisted. Thê thermocouple observations of Mercury showed no temperature jump at the terminator, which was a little puzzling, but could be plausibly accounted for by librations. Temperature readings for the centre of the dark hemisphere gave an uncertain figure of about −70°C, which seemed rather high for an eternal night. On the other hand, the blackbody radiation curve has a strongly marked maximum, which at such low temperatures falls below the infrared range accessible to the thermocouple, so that this result could not be considered very reliable, and required confirmation by microwave radio observations.

In any case the late Astronomer Royal Sir H. Spencer Jones did not accept the synchronous rotation of Mercury as the final solution of the problem in his *General Astronomy*, published in 1951.

The bulk of astronomical opinion, however, was not greatly affected by such doubts and reservations, and rested content with having the matter settled and done with. Yet the investigations of the microwave radio emission by Mercury were soon to change all this.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S. Prometheï
S. Persephones
SOLITUDO
HERMÆ TRISMEGISTI
S. Panos
S. Iuis
Cyllene
S. Atlantis
Hesperis
S. Mantis
S. Iovis
S. Maiae
Helii Prom.
Phaethontias
Pieria
Ixionis vallis
Horarum vallis
S. Lyræ
S. Phœnicis
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S. Lycaonis
S. Criophori
Heliocaminus
Pleias
Neptuni vallis
Admeti vallis
Aurora
Argyritis
Pentas
S. Alarum
S. Argyphontis
S. Dionysi
Liguria
S. Aphrodites
Caduceata
Apollonia

Fig. 1.

Several of these were made in 1965. Kellermann's study of the 11-cm radiation yielded a comparatively high temperature of −23°C for Mercury's antisolar point, which should be the more significant as the bulk of this emission would originate some 1–2 feet below the surface, where the low temperatures of perpetual night could not be significantly relieved by atmospheric circulation. Barret, working with shorter wavelengths, found a still higher mean of +27°C for the dark hemisphere.

It is true that these were 'brightness temperatures', and a brightness temperature is calculated from the energy of the emission on the assumptions that all of it is thermal in origin and that the emitter radiates as a black body. The latter may be near enough to the truth, considering that the visual albedo of Mercury is 0·06, but the unreliability of the former assumption is dramatically demonstrated by the result of E. E. Epstein's observations at 3·4 mm, which gave consistently the same brightness temperature of −73°C for both the dark and the sunlit hemisphere of Mercury.

Whatever the ultimate explanation of these thermal anomalies may be, it was fairly clear that Mercury's night hemisphere could not stay permanently averted from the Sun.

The problem can be tackled by the two-way radio-astronomy, or radar. The only difficulty lies in the weakness of radar echoes from Mercury, which necessitates superimposing a large number of echo graphs, to smooth out the accidental irregularities and so obtain a significant result. When, however, the 1,000-foot fixed paraboloid of the Arecibo Ionospheric Observatory in Porto Rico came into operation late in 1963 the difficulty of the procedure could be greatly reduced. The dish is fixed and looks vertically upwards, but it permits observations to be made within 20° of the zenith, and was extensively used to study the bright planets, including Mercury, in 1964 and 1965.

There are three possible ways of deducing the axial period of a planet from the radar echoes.

If the various parts of the planet's surface differ in radar reflectivity, the intensity of the echoes will fluctuate periodically, and, being given a sufficiently long series of consistent observations, the

period of rotation can be determined. This method, however, is lengthy, laborious and not free from ambiguity, though it presents the advantage of being unaffected by axial inclination.

This is not true of the Doppler shifts caused by rotation. With sufficient power and gain of antenna, a Doppler-shift method based on delay can be used with radar. A planet is spherical, and the radar echo from the centre of the visible disk, or the sub-radar point, arrives first, followed with increasing delay by the echoes from the successive annuli of the disk outwards to the limb. An echo of each successive annulus can be isolated by appropriate timing. If the planet were not in rotation the wavelength of the emitted radar pulse would be unaffected in the echo by shifts other than those arising from the rotation of the Earth and the orbital motions of the Earth and the planet, which are all known and can be easily allowed for. But on a rotating planet one limb is approaching and the other receding, and this causes the echo wavelengths to be spread out more and more in annuli of successively wider radius, until a maximum spread is reached at the limb. The resulting graph (for Venus) is shown in Figure 2.

This graph also shows spikes and hollows due to the differential reflections from the surface. As the planet turns round these spikes and hollows travel across the reflection diagram from the shorter to the longer wavelength, and the time of complete transit corresponds to a half of the axial period. This is the third alternative, which so far cannot have been applied to Mercury. In 1965, however, its axial period was found at Arecibo by the second method to be 59 ± 5 days. The error margin measures only the internal consistence of the observations and so does not include the main possible source of error arising from the inclination of the polar axis, which was assumed to be nil, i.e. the axis was taken to be normal to the orbital plane. Any neglected inclination would shorten the period.

In theory the spatial orientation of the polar axis should be revealed by the fluctuation in the axial period when this is measured at different points of the orbit. Yet the procedure is lengthy and difficult, and of little value with so long a period where the

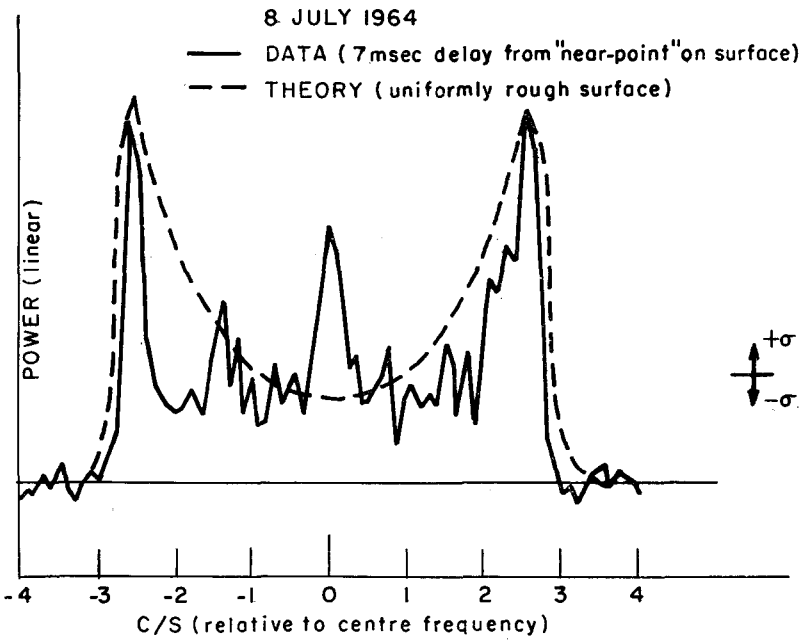


Fig. 2.

fluctuation may be less than the probable error of the determination. The result obtained in this way for Venus is badly out of joint with other data and does not seem to inspire much confidence.

Since then it has been shown by S. J. Peale and T. Gold that with an orbit as eccentric as Mercury's it is dynamically possible for tidal forces to yield any period between 56 and 88 days. MacGovern, Gross and Rasool claimed to have established a direct axial period of 58 $\pm$ 0·4 days by visual observation. Thus the horse having bolted, the stable door is well locked. Nevertheless, we cannot simply throw out the painstaking labours of Antoniadi and Schiaparelli, who found the period to be synchronous, without a convincing explanation.

This appears to lie in a peculiar set of coincidences between the

various periods. Thus Mercury's synodic period is approximately twice its axial period, as well as being four-thirds of its orbital period and one-third of the terrestrial year. Owing to this, after a synodic period, in which the phases recur, Mercury will have turned twice round, thus presenting the same part of the surface to view. In addition, as a result of the second coincidence every third western or eastern apparition is a favourable one, during which most successful observations are likely to be made. These apparitions must obviously be six axial periods and also one year apart, so that once more Mercury will turn the same side to the observer.

The coincidences are imperfect and a long series of observations should eventually reveal the true state of affairs. But the sidereal period of 59 days corresponds to a solar day of 180 our days, so that in 24 hours rotation will carry the Sun through an angle of barely 2° in the Mercurian skies. The effect of libration near perihelion is about twice as large, so that without prior knowledge it is not easy to distinguish between the two.

Last year Henri Camichel and Audouin Dollfus combined a systematic visual and photographic study of Mercury and the Pic-du-Midi and Meudon Observatories with a statistical examination of the earlier drawings, including those done by Antoniadi and G. Fournier. Their method consisted in establishing the dates on which the particular surface markings and so the central meridian occupied the same position as seen from the Earth. The intervals between these dates, corrected for the effects of the Earth's rotation and orbital movement, must be integral multiples of the sidereal axial period of Mercury. Some multiples being incompatible with the appearance shown in other drawings, the true period is obtained by a process of elimination. The result was 58·5 days, or exactly two-thirds of the orbital period, in excellent agreement with the radar and dynamical data.

The unknown factor is the inclination of the axis. It would affect the radar result in proportion to the cosine of the angle i, making the radar period this much longer than the period obtained direct from the movement of the surface markings, as in the latter case.

A difference of about 1 day would be consistent with an inclination of up to 10°, and some such difference does appear to exist. Since the inclinations of the axis to the line of sight will vary with the position of the planet and the Earth in their orbits, no accurate evaluation is possible at the present moment, but with an inclined axis the circumpolar regions will have a polar day of 88 days only, and so less than a half of the rotational solar day. The existence of strong librations in longitude will further complicate matters as the polar circle is approached, which will result in a most peculiar solar régime, the Sun rising and setting several times a day!

The Aurora

H. G. MILES

From an observer's point of view most astronomical phenomena are relatively devoid of colour. One notable exception, however, is found in the auroræ or polar lights, seen at their best from reasonably high latitudes. Arctic explorers have throughout history returned with graphic descriptions of the appearance of the heavens during a display. In the middle of the nineteenth century the Arctic explorer Sir John Hobbs tried to explain the phenomena as caused by 'the action of the Sun, when below the pole, on the surrounding masses of coloured ice, by its rays being reflected from the point of incidence to the clouds above the pole which were before invisible'. He performed several experiments to show, amongst other things, that in the Antarctic coloured auroræ are never seen!

At lower latitudes, the auroral displays are seen less frequently, the frequency decreasing rapidly as the equatorial regions are approached. Nevertheless history records many interesting incidents involving low latitude displays. It is said that on one occasion the Roman Emperor Tiberius, seeing a red glow in the northern part of the sky, thought that the port of Ostia was on fire and sent his troops to help extinguish the flames.

Many weird and wonderful theories have been put forward to explain these displays; but as early as 1716, Halley suggested an electrical discharge associated with the Earth's magnetic field. It is, however, interesting to recall the description written in Flammarion and Gore's *Popular Astronomy* published in 1894.

'Our planet is alive with a certain stellar life which we cannot yet sufficiently understand. Magnetic currents circulate in it and, incessantly, under their mysterious influence, the magnetic needle

seeks the north with its restless and agitated finger. . . . We may add that every day this curious needle deviates from its magnetic meridian towards the east at eight o'clock in the morning, and towards the west at one o'clock in the afternoon. The extent of this variation varies year by year, and, what is truly surprising, this variation appears to correspond with the number of spots visible on the Sun. The number of Auroræ Boreales seems likewise connected with the state of the day star. Indeed, the magnetic needle enclosed in a cellar of the Paris Observatory *follows* the aurora borealis.'

Although it had been reasonably established that there were strong connections between auroral displays and sunspot activity, this did not prevent other ideas being put forward. The meteor shower of 1872 was accompanied by an auroral display; and although solar activity at that time pointed to the possibility of a display, ideas were put forward that 'displays have too often figured as an accompaniment of star showers to permit the coincidences to rank as fortuitous'.

Twenty-five years after Halley had suggested an electrical explanation, Hjorter established the association between displays and the behaviour of a magnet, a result substantiated by the work of Arago at the beginning of the nineteenth century. By half-way through the century, the close similarities between the frequencies of the displays and sunspot activity were firmly established, although the mechanism was by no means understood, nor was the idea of a solar-terrestial link wholly accepted. Lord Kelvin, in 1892, could not accept the idea of any direct magnetic action by the Sun upon the Earth, because of the tremendous amount of energy required.

By the turn of the century, however, it was generally accepted that the primary cause of auroral displays and magnetic storms was electrically charged radiation emitted by the Sun. Birkeland carried out many experiments to find a mechanism and was able to explain the existence of the auroral zone and how it was possible for radiation to impinge on the Earth on the night side. Much progress was made in the following years, but it was the Polar

Year 1932–3 that provided much of the observational evidence upon which the modern theories have been developed. Observation posts were set up at strategic positions in northern Europe and Canada and made systematic routine observations, an essential requirement for investigations of this type. Sites were also set up in the Antarctic to supplement the information gained from previous expeditions to that region.

Although much of the visual observing can be more conveniently carried out by the full-time worker, auroral observing is one of the few fields in which the amateur can still hold his own. All that is required is an observing site well away from artificial lights and with an unobscured northern horizon. Even if these conditions are not possible, he can still record valuable information on occasions of the more spectacular displays. The only equipment needed by the lone worker is a watch, a subdued red light, pencil, paper and some method of measuring angles from the horizontal. In fact during a strong display, it is often possible to dispense with the light. The method of recording a display has been standardized using symbols to record the main features. The standard report form with the recognized symbols is used by members of the Aurora Section of the British Astronomical Association, directed by J. Paton of the Balfour Auroral Laboratory at Edinburgh. Systematic reporting of the presence or absence of aurora on all nights when it is possible permits the construction of charts showing the limits of visibility. For observers in lower latitudes, observations will normally be limited to the more spectacular displays which unfortunately occur infrequently, but the sighting of a display is more than sufficient reward for the weeks or possibly months of negative reports.

For the spectacular displays it is not necessarily true that the farther one travels northwards the better will be the display. The great display on 1938 January 26 was visible in all its glory from central Europe, but from Tromsø, in northern Norway, only faint activity could be seen in the southern part of the sky. These more spectacular events normally occur during sunspot maximum, and the maximum of 1957–8 was no exception. Several quite strong

displays were seen from all over England. These years were designated the International Geophysical Year and during this period aurora and other related phenomena were observed in great detail. Many amateurs took active parts in the programme. Because of the peculiar effects on the quality of picture obtained on the author's TV set, it was possible on occasions to suspect that a display was occurring when the sky was overcast. In fact, on one such occasion, a careful search through a small break in the cloud cover showed a greenish coloured pulsating ray. Subsequently the TV was used as an 'alert' for a more prolonged watch. The idea of using 'alarm bells' is by no means new. Many years ago, Stormer, one of the leading workers in this field, used the fluctuations in the voltage in telegraph cables to give him advanced warning to prepare for an evening work.

Normally, from a position say in England, a display starts as a faint glow on the northern horizon, the glow gradually climbing higher in the sky. This glow is really the upper part of a display appearing overhead much farther to the north. The increasing altitude of the glow corresponds to the southward movement of the display. After a time, one realizes that the glow does not reach right down to the horizon and that it has taken the form of an arc, with the sky below it appearing black. It is the position and height of this arc that is important from a theoretical point of view. Frequently the lower border of the arc is fairly well defined but the upper edge diffuse and irregular in shape. Recording the altitude of the lower edge should be carried out regularly, and the times at which changes occur recorded. Although one can never be sure of the way in which a display will develop, there are certain features which occur frequently. Small changes in the appearance and position of the arc may suddenly give way to a far more active bow with shafts of light shooting from its upper edge. These rays may be white, green or red in colour and may have an apparent east–west movement, the so-called 'draperies'. As the display develops the arc may appear to fold and may even appear as a double arc. After maximum activity one often gets a pulsating effect when the light surges upwards in a wave motion. As the display dies down,

one sees spasmodic bursts from the arc and finally the arc becomes more and more diffuse until all that is left is a faint glow. Although the rays appear to diverge from the arc, they are in fact roughly parallel, following the lines of force of the Earth's magnetic field. At times one might see patches of diffuse light appearing in various parts of the sky, whilst at other times the display may appear so complex giving the impression of complete disorder. Generally, however, one can catalogue the various types and by using the standard code used by all serious observers log down all the main features of a display quickly and easily, and what is important, in a way that is useful for comparing reports from other observers.

It has been known for over 200 years that closely associated with the aurora are the magnetic storms, at which time the compass does not point to the north magnetic pole. In the last 40 years, most people have noticed in one way or another the unreliability of radio signals at such times. Radio communications can break down completely, but at other times radio links occur when at normal times this is impossible. At relatively long wavelengths, in the region of 20–30 kHz, the background noise in a receiver increases by a considerable factor. One source of this background noise is the noise caused by tropical thunderstorms. Under abnormal conditions the ionized layer in the upper atmosphere which reflects the radio waves of this wavelength forms at a much lower level than under normal conditions, resulting in a more efficient reflection of the noise. It is interesting to compare the trace obtained at 27 kHz with the visual observations made during a display on 1958 April 16 (Fig. 1). The pen recorder traced out the relative intensity of the background noise from 1800 to 2200 hr. At the beginning of the period one can see the position for normal conditions. The intensity of the signal started to increase at about 1900 hr. After 2000 hr, superimposed on the gradually increasing background noise were frequent peaks of enhanced noise. Towards the end of the period, the strength of these bursts decreased. Unfortunately, no visual observations were made during the early part of the period because of cloud cover. The following notes have been adapted from the author's record of the display. Prior

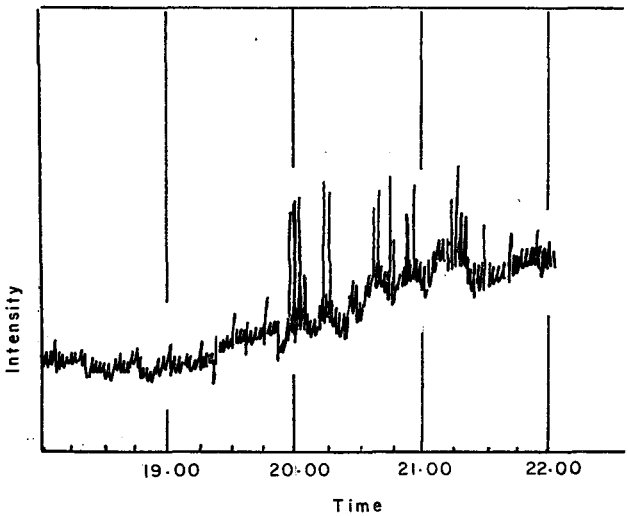


Fig. 1.

to 2045 hr, when times observations began, very bright rays had been seen.

2045 hr	strong white rays radiating like a fan from the northern horizon reaching to angle about 20 degrees beyond the zenith.
2046	prominent surface just above horizon 15 degrees west of north.
2051	surface getting stronger and appears to be developing into a ray.
2053	many rays; those in the NNW and in the NNE being brighter than those in the north.
2055	activity much lower with only the outside rays visible.
2058	activity increasing again with rays brightening but getting shorter in length.
2100	arc developing?
2105	rays and glow fading.

2107 hr glow brightens up suddenly.
2108 glow fades – all trace of rays gone.
2114 glow visible through cirro-stratus cloud.
2216 ray activity behind cloud suspected by changes in brightness.
Cloud interfered with observations after this time.

As mentioned earlier it has been accepted for a considerable time that there was a close connection between auroræ, magnetic storms, radio fadeouts and solar activity. Only recently however has it been possible to remove some of the difficulties which prevented an overall satisfactory explanation for the mechanism. The advent of artificial satellites and deep space probes has helped considerably, but even so much work still remains to be done.

It is now known that the Sun is continually ejecting material mainly in the form of electrons and protons, the so-called solar wind. Due to the rotation of the Sun, the solar magnetic field extends outwards radially roughly in the form of a spiral, very similar to the effect one obtains with a lawn sprinkler. When a solar flare occurs, a cloud of plasma is ejected from the region of the flare; and because the energy of the particles is greater than that of the normal solar wind, the Sun's magnetic field is modified. It is thought by some workers that the kinetic energy is so great that, as it leaves the Sun, it carries with it part of the Sun's magnetic field, forming a magnetic tongue of plasma. This plasma tongue travels away from the Sun at velocities between 1,000 and 2,000 Km/second with a hydromagnetic shock wave leading the way. When this meets the geomagnetic cavity, i.e. the outermost portions of region where the Earth's magnetic field predominates, the boundary is compressed inwards towards the Earth, causing a sudden commencement of a magnetic storm. A short time later the actual plasma tongue arrives, and some of the protons and electrons are trapped in the Earth's magnetic field. These cause an electric current to flow round the Earth, the so-called ring current. This in turn modifies the Earth's magnetic field and hence produces some of the phenomena so familiar to us. Not all solar flares

produce magnetic storms. Possibly in some cases, the plasma tongue breaks up before it reaches the Earth, and at other times the tongue may not pass anywhere near to the Earth.

Although the idea of trapped protons and electrons in the upper regions of the atmosphere had been put forward for some time, it was the discovery of the radiation belts by Van Allen in 1958 that caused the break through. Both the United States and the Soviet Union have sent up many satellites and space probes to study these regions, and gradually a satisfactory picture is emerging.

At one time it was thought that the trapped electrons from the plasma tongue were responsible for the auroral displays, but now it is realized that, from an energy point of view, this is impossible. More recent ideas suggest that the plasma tongue, in distorting the Earth's magnetic field, causes the low-energy electrons already in the radiation belts to be accelerated. These, together with some of the plasma electrons, enter the atmosphere at high latitudes. They collide with the oxygen and nitrogen atoms and also the nitrogen molecules and the resulting 'excited' atoms, emitting light we know as the aurora. The various colours appearing in the displays are due to the varying states of ionization of the atoms and molecules produced when subjected to this bombardment. Most of the interaction occurs at heights of between 100 and 300 km above the Earth's surface, the heights normally associated with auroral displays. The green colour frequently seen is attributed to atomic oxygen, whose spectrum contains the green line at 5,577 Å, one of the so-called forbidden lines. The red colour is due to both atomic oxygen (at 6,300, 6,364 and 6,391 Å) and to the band spectra of neutral and ionized molecular nitrogen. Molecular nitrogen is also partly responsible for the blue and violet colorations.

In the northern hemisphere, the auroral zone is situated at a magnetic latitude of 65–70°, but that in the southern hemisphere is in a position a few degrees nearer the south magnetic pole. Generally displays occur in both hemispheres at the same time. This was thought to be the case, but was observationally confirmed by work carried out during the International Geophysical Year in 1957–8. This fact agrees well with the idea of charged electrons

being trapped in the radiation zones and travelling to and fro between the mirror points. The creation of artificial auroræ by exploding nuclear bombs at high altitude has confirmed this. On 1958 August 1 and 12, bombs were exploded by the United States at heights of 80 and 44 km above Johnstone Islands in the Pacific Ocean (16°N). In each case brilliant auroræ were seen immediately in the area and a minute later in the Samoan Islands (14°S) 3,200 km away. Further bombs were exploded a few weeks later at heights of about 500 km, producing similar effects. After the 'Starfish' explosion in 1962 from Johnstone Island, the aurora was seen from New Zealand nearly 5,000 km away.

Even if scientists are well on the way to explain the mechanism whereby auroral displays are formed, this does not reduce in any way the pleasure in observing one of the most beautiful natural phenomena man is able to witness. With the coming of sunspot maximum, it is likely that there will be within the near future a repetition of the displays seen in the past at times of maximum solar activity. The chances of seeing a display will be increased considerably if a large solar flare happens to occur at times near to the equinoxes, March and September, the best times of the year for observing a display from regions outside the normal auroral zones.

Mars: A Sterile Planet?

PATRICK MOORE

'Is there life on Mars?' This question has probably been asked more often than any other in astronomy. Even now the answer to it is not known, but new information obtained during the past few years must, unfortunately, make the Red Planet seem less attractive than astronomers had believed. The days of Percival Lowell's canal-building Martians seem very far in the past.

Mars comes to opposition on 1969 May 31. It is actually at its closest to us on June 9, and this is a reasonably favourable opposition, but southern-hemisphere observers will have the best of it, because Mars is well south of the celestial equator. It lies in Scorpio, not far from Antares, and it will be interesting to compare the colours of the two objects. Mars, of course, will be far the brighter, and will have a magnitude of $-2{\cdot}1$, far superior to any star – even the brilliant Sirius. The disk will have a maximum diameter of $19\frac{1}{2}$ seconds of arc, though it must be admitted that so far as British observers are concerned the advantages will be largely cancelled out by the low altitude.

Much the most prominent of the dark markings on Mars is the rather V-shaped Syrtis Major, which lies not far from the equator of the planet. It was first seen by Christiaan Huygens as long ago as 1659, and is unmistakable. In the earlier charts of Mars it was known as the Kaïser Sea or the Hourglass Sea, but the present name, introduced by Schiaparelli in 1877, has long since been accepted.

When Mars is fairly near opposition, the Syrtis Major may be seen with a small telescope. It will not be very well placed during 1969, because the southern hemisphere will be tipped away from the Earth, but there should be no difficulty in making it out with

any instrument larger than 3-inch aperture. Unfortunately the remaining dark markings are much less easy. A 6-inch aperture will show the main ones, such as the Sinus Sabaeus, the Mare Sirenum, and the Mare Erythraeum in the south and the Mare Acidalium in the north, but it must be admitted that the fine details shown on many published charts of Mars are beyond the reach of modest telescopes.

The official map of Mars is that compiled under the auspices of the International Astronomical Union. It shows considerable detail but it also shows large numbers of the famous (or notorious!) canals, which, in the view of many observers, simply do not exist as hard, straight, narrow lines. Whether this is so or not, moderate telescopes will show no canals, though it is easy for the human eye to be deceived when straining to glimpse details at the very limit of visibility.

Mars has a relatively eccentric orbit, which is why not all oppositions are equally favourable. This year's is one of the closest for some time. Past and immediate future data are as follows:

Opposition	*Min. distance from Earth* (miles)	*Max. apparent diameter* (seconds)	*Position*
1963 Feb. 4	61,800,000	14·0	Near Xi Leonis
1965 Mar. 9	61,800,000	14·0	Near Beta Leonis
1967 Apr. 15	56,200,000	15·4	Near Spica
1969 May 31	45,300,000	19·5	Near Antares
1971 Aug. 10	34,600,000	25·0	Near Zeta Capricorni
1973 Oct. 25	40,600,000	21·6	Border of Pisces and Aries
1975 Dec. 15	53,100,000	16·5	Near Zeta Tauri

The 1971 opposition will be much better than that of 1969, both because Mars will be closer and because it will be farther north. However, during the coming spring moderate telescopes will show considerable detail. The north pole of Mars will be tilted toward the Earth, but the large south polar cap should appear in June; toward the end of September it will shrink rapidly, and this is the time to look out for the dark bordering 'Lowell band', often

thought to be due to temporary moistening of the ground as the cap decreases. Of the northern markings, the most prominent is sure to be the Mare Acidalium, whose rather wedge-shaped aspect is well known to every observer of the planet.

It must be admitted that fairly large telescopes are needed for useful research work to be carried out in connection with Mars. Perhaps the most important line of investigation is with regard to clouds, which are by no means uncommon. Our knowledge of the wind-system is still rather rough, and cloud drifts provide valuable data. The minimum useful telescope aperture is probably about 8 inches, but 10 to 12 inches is obviously better; results with smaller apertures are bound to be rather suspect.

There have often been claims that in British climates no telescope larger than 12-inch aperture or so can profitably be used for Mars. With this viewpoint I strongly disagree. It is my experience that the larger the telescope used, the more detail will be seen, despite the troubles due to our own unsteady atmosphere. Of course, this applies only when observing conditions are reasonably good, but otherwise there is little point in studying Mars at all – whatever may be the instrument used.

In the 1963 *Yearbook* an important review article about Mars was written by the eminent French astronomer Gérard de Vaucouleurs, recognized as one of the leading authorities on the subject. This summarized what was then known. Since then, however, the American probe Mariner IV has flown past Mars, and sent back information which has altered the whole picture. We now know that the surface is crater-scarred, and that the atmosphere is appreciably thinner than had previously been thought. Neither is the atmospheric composition as expected; instead of being chiefly nitrogen, the main constituent appears to be carbon dioxide.

It is this new information about the atmosphere which is so vital in trying to answer the problem of whether Mars is life-bearing or sterile. Previously, it was thought that the ground density must be roughly equivalent to that of the Earth's air at a height of about 55,000 feet above sea-level. This would be far too

thin for any Earth-type mammal to breathe, and there was never any suggestion that an astronaut would be able to go to Mars and walk about in the open unprotected. Nothing of the kind would be possible even if an atmosphere of Martian density were made up of pure oxygen; human lungs could never function under such conditions. On the other hand, there did seem to be a chance that an astronaut would be able to dispense with most equipment other than breathing apparatus, and it was not thought definite that full-pressure suiting, as used on the Moon and in space, would be needed near Martian noon, when the temperature rises to over 60 degrees Fahrenheit.

When Mariner IV went behind Mars in the famous 'occultation experiment' of 1965, signals from it came to us through the Martian atmosphere, and it was these signals which provided us with the new information. It now seems that the ground density is no more than that of the Earth's air at between 95,000 and 100,000 feet above sea-level, which is a very different matter. It means that full-pressure suits would be required all the time. More important still, it indicates that the Martian atmosphere is of relatively little use as a shield against harmful radiations coming from space; and it is this which has led many astronomers to have serious misgivings about life of any sort there.

When the dark markings were first seriously studied, a very long time ago, they were tacitly assumed to be seas. This attractive idea became untenable when it became clear that Mars is desperately short of water, and in 1878 Liais, a French astronomer who spent most of his working life in South America, suggested instead that vegetation might be responsible. This seemed eminently reasonable, and remained the general view until recently. Indeed, probably it still does; but there is a growing body of opinion nowadays that some inorganic explanation must be sought.

Advanced plants, such as trees and flowers, were always known to be out of the question, because of the thinness of the atmosphere and the intensely cold night temperatures. On the other hand, some varieties of organisms, such as lichens and mosses, are notoriously hardy – and there are some lowly organisms which can

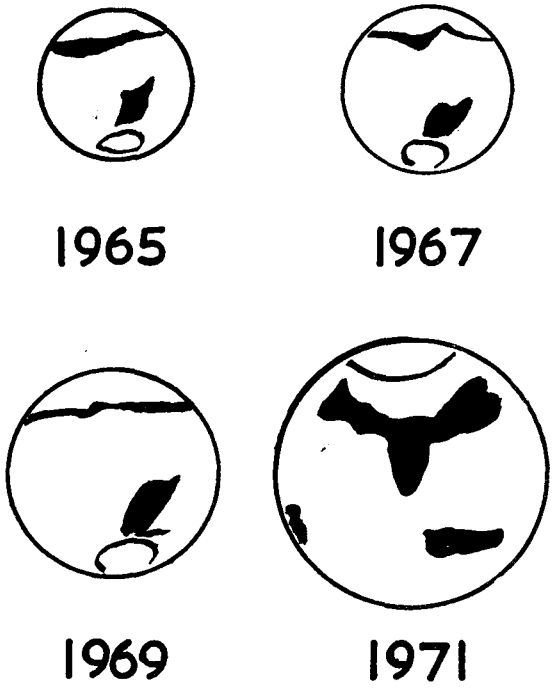
survive under very hostile conditions indeed. In Russia, G. A. Tikhov founded the school of 'exobiology', and compared the Martian organisms with those found in various inhospitable environments on Earth, such as high-altitude tundra regions. E. J. Öpik pointed out that since dust is often raised from the ochre areas, the dark areas would soon be covered up if they possessed no regenerative power.

There is also the matter of what has been called the 'wave of darkening' which takes place every Martian year. As the polar cap shrinks, either by melting or by sublimation, the dark areas in high latitudes of the hemisphere concerned seem to harden and sharpen, as though the organisms were being revived by the arrival of moisture; this process continues down toward the equator. Yet it must be said that the phenomenon is not nearly so well-marked as many books and papers claim. I have been observing Mars for many years, and I have seen the effects of the 'wave of darkening', but to my eyes the phenomenon is neither consistent nor pronounced. However, it does certainly occur, and an organic hypothesis provides a logical explanation.

Some years ago W. M. Sinton, in America, announced that the spectra of the dark areas contained lines which seemed to be of organic origin. For a while this was regarded as more or less conclusive proof of life on Mars, but, disappointingly, it now seems that there were errors in interpretation, and the evidence from this investigation is no longer regarded as acceptable.

Nobody ever denied that the organic theory had weak points, but none of the alternatives seemed to be nearly so plausible. Svante Arrhenius suggested hygroscopic salt deposits to explain the dark areas, but the amount of available moisture was soon found to be patently insufficient. The volcanic theory of D. B. McLaughlin was no better. Here it was assumed that volcanic ash was regularly spread out from active volcanoes at the tips of the 'pointed' areas such as the Syrtis Major; but to suppose that the ash would be blown regularly into exactly the same positions was not reasonable, despite the relative flatness of Mars and the probability of more or less consistent atmospheric movements of the

trade-wind variety. Another opponent of the organic theory was the late V. V. Sharonov, of Leningrad. On the whole, however, the existence of Martian organisms was widely favoured – at least up to the Mariner IV flight of 1965.



Relative maximum apparent diameter of Mars at different oppositions

Mars had always been regarded as more Earthlike than any other planet. Yet Mariner showed that the surface was covered with lunar-type craters, and so the general aspect was much more like that of the Moon. The origin of these craters is still a matter for debate. They may be due to either vulcanism or to meteoric impact. Fielder, in the 1967 *Yearbook*, gave reasons for supporting

a volcanic origin, and this is also my own view, but the evidence is still inadequate for a decision to be made either way. We may not have to wait for further Mars probes. If the origin of the lunar craters can be solved, as is likely in the reasonably near future, then the answer to the Mars puzzle will also be known, since there can be little doubt that the two types of structure are essentially similar.

On its own, the existence of Martian craters is no obstacle to the existence of life there. And little time need be spent in discussing the canals, once regarded by Lowell and others as proof of intelligent activity. No Lowell-type canals were shown by Mariner IV, and nobody expected them to be. That the canals have a basis of reality is unquestioned, but they are neither straight nor artificial-looking, and there can be no doubt that they are natural features.

With regard to Martian life, almost everything hinges upon the quantity and character of the atmosphere. Life on Earth can exist only because layers in the upper air act as an effective shield against harmful radiations. If the atmosphere of Mars is as tenuous as we now believe, can it provide a true radiation screen? If the answer is 'no', then we must discount life there, at least on any terrestrial pattern; organisms could never have been produced, and they could not survive in any case. And this is why many authorities, particularly biologists, tend to regard the planet as sterile.

There is doubt, too, as to whether dark areas such as the Syrtis Major and the Mare Acidalium are depressions, as has always been believed. Sagan and others consider that they are more likely to be elevations, and there are suggestions that the canal strips may be mountainous, even though it is unlikely that Mars has any chains of peaks comparable with those of Earth. Here again we must await more information.

Telescopic observations carried out from Earth are limited. During the best period of the 1969 opposition, a magnification of almost 100 will be needed to make Mars seem as large as the Full Moon looks with the naked eye – and this is not very good. No telescope will give a better view of Mars than can be obtained of the Full Moon with good binoculars, and we can never take

advantage of shadow phenomena, because the phase of Mars is never sufficiently pronounced. What would we know about the Moon if we could see it only when full, and with binoculars? Comparatively little; and this is our plight with regard to Mars, unless we use space research methods.

Very probably there will be more Mars probes in the near future. The Russians have not yet made any announcements about their plans, but their triumph with Venus IV, which made a soft landing on that planet in 1967, shows that they have overcome many of the troubles that have handicapped them since the start of the Space Age, so that it will be most surprising if they do not attempt something similar for Mars. At the time when I write these words (March 1968) the American probe programme has been officially curtailed, mainly because of the financial strain of the Vietnam war, but it is still hoped to dispatch a probe to orbit Mars and draw up a full map of the surface. This will almost certainly be done during the 1970s, come what may.

At the moment we have only Mariner IV to guide us, but the photographs covered both the light and the dark areas, so that they are probably representative of the whole of the planet. Any last lingering doubts about oceans or linear canals have been killed, and we must now regard Mars as an extremely hostile world, much more similar to the Moon than the Earth.

Yet the Martian atmosphere, tenuous though it may be, will still act as a fair shield against meteoroids, even if not against radiations – and this alone should make Mars somewhat less forbidding than the Moon. Whether there are any useful materials there, or any underground supplies of water, remains to be seen.

If all goes well, the unmanned probes will be followed in due course by manned expeditions, but this takes us very far into the future – further, it seems, than appeared likely before 1965. It will be essential to set up some sort of base there, but no plans can be made until we know much more about the conditions than we pretend to do at the moment. Some years ago – it must have been about 1960 – I was hotly criticized for writing that in my view it would be wildly optimistic to expect a journey to Mars before the

end of the century. I am still of this opinion; I hope I am wrong, but I fear not.

In short, we cannot yet say whether Mars is living or sterile. The most we can hope for is a certain amount of primitive organic material, and even this is not uncertain, but it is too early for us to make any positive statements.

Meanwhile, Mars will be observable for much of 1969; useful observations with adequate telescopes can be started in the late winter and continued through to the end of the autumn. No ordinary telescopes will show the craters (the only report of such an observation is that of E. E. Barnard, with the Lick 36-inch refractor, and even this seems to have been mysteriously lost), but there ought to be clouds to be seen, and notes of their aspect and movement will be valuable. Look, too, for indications of the 'wave of darkening' as the cap shrinks, and for the dark Lowell band round the rim. Large instruments will also show the two dwarf moons, Phobos and Deimos, which are often – and justifiably – regarded as the most remarkable satellites in the whole of the Solar System.

Mars remains a problem planet. It may or it may not harbour lowly life. Yet even if it proves in the end to be sterile, it must still be regarded as one of the most fascinating of all worlds known to us.

Recent Advances in Astronomy

PATRICK MOORE

It is seldom nowadays that a year passes by without some fundamental new development in astronomy. The period covered by this brief review (mid-1967 to mid-1968) has been no exception, and indeed the discovery of the remarkable radio sources now called 'pulsars' may be one of the most important events of the decade so far as astronomers are concerned. Quasars were puzzling enough; pulsars may be even more so, though in a rather different way. For a time it was even thought just possible that the signals from the pulsars were of artificial origin, though it was not long before this intriguing idea – known inevitably as the L.G.M. or 'Little Green Men' Theory – was soberly and firmly disproved.

The story really began in 1967, with the erection at the Mullard Radio Astromy Observatory, Cambridge, of a new and very sensitive aerial covering 4½ acres. Before long it was found that certain signals, at first thought to be due to weak and sporadic interference, were linked with specific positions in the sky. Systematic studies of them began in November 1967, and it was found that the signals came in rapid pulses, each lasting about 1·337 seconds, and remarkably regular. Two more similar sources were then found, and a third with a pulsation rate of only about a quarter of a second. In fact, it seemed that the radio astronomers had discovered 'ticking sources', and it was then that the L.G.M. theory had its brief moment of near-credibility.

However, it soon emerged that the sources could not possibly be of artificial origin. They were a considerable distance away (probably a few hundreds of light-years), and the signals showed none of the characteristics that might have indicated deliberate

transmissions. No visible objects could be seen in the positions of the objects, which were inevitably christened pulsars, and a first theory suggested that they might be very faint white dwarfs or neutron stars.

A white dwarf represents a very late stage in stellar evolution.[1] It has been aptly described as a bankrupt star; most of its matter is in a degenerate state, and it has no nuclear reserves left, so that it is relatively small but extremely dense. Sirius B, the best-known member of the class, has a diameter less than that of the planet Uranus, but about the same mass as that of the Sun; many more extreme examples are known, a few of which are no larger than the Moon. There is every reason to suppose that white dwarfs are extremely common in the universe, and they have been exhaustively studied during the past fifty years or so. On the other hand, why should a white dwarf pulsate so quickly? A pulsation period of a few hours would be rational enough, but to vibrate in less than a second, as at least one of the pulsars seemed to be doing, was straining credibility to a marked degree.

White dwarf material is very dense indeed; a thimbleful of it would weigh hundreds of tons. It had been suggested that an even more extreme case of density would be a neutron star, where a thimbleful of material would weigh hundreds of millions of tons. Neutron stars have been the subject of theoretical investigation for some time – they were once, briefly, thought to be the causes of X-ray sources – but no neutron stars had been actually observed, so that their existence was strictly non proven.

The white dwarf or neutron star idea was proposed in early 1968 by five Mullard astronomers.[2] The main difficulty lay in deciding why a white dwarf should pulsate with such rapidity. The Cambridge team suggested that radial pulsations would generate hydromagnetic shock fronts at the star's surface, which would be accompanied by bursts of X-rays and energetic electrons.[3,4] Then, in the following month, Ryle and Bailey[5] tentatively identified one of the pulsars with a blue 18-th magnitude object which they though might be the first observed neutron star; astronomers at Jodrell Bank also came down in

favour of the general idea,[6] and stated that everything seemed to point to an origin in the condensed corona of a collapsed star of the white dwarf or neutron type. In the same month came the idea of a neutron binary star.[7] Another trouble, however, was that although the periods of the pulses seemed to be absolutely constant, the amplitudes were not – and why should this apply to a star which was vibrating so consistently? In America, Ostriker suggested[8] that the signals might come from active regions on white dwarfs which were spinning round remarkably quickly, though a rotation period of less than a second seemed again to be rather improbable. In April, Hoyle and Narlikar[9] produced another theory – that the pulses were emitted by collapsing supernovæ in suitable circumstances. Further details of the four pulsars were given in the same month by the Cambridge team,[10] and it was shown that the vibrations really were due to the sources and not to what might be termed interstellar or interplanetary scintillation. Also at Cambridge, Bailey and Mackay[11] used the one-mile radio telescope to fix the position of one of the pulsars very accurately, and to show that there was no obvious identification with an optical source. Serious doubts were cast on the binary star model by Scott and Collins,[12] and also upon a theory that the pulses might be triggered off by a satellite moving quickly round a neutron star (Pacini and Salpeter, U.S.A.[13]). Then Faulkner and Gribbin, at Cambridge,[14] put forward calculations to show that there might be ways of overcoming the objections to a white dwarf's vibration at such a rate – bringing us back once more to the very start of the investigation.

The whole matter has been completely puzzling, and at the time when I write these words (June 16, 1968) no solution has been forthcoming. As with the quasars in 1963, astronomers have suddenly found themselves confronted with a situation which had been completely unsuspected, and which appeared at first sight to be incredible. Yet we must not give too great a link between quasars and pulsars. Quasars are generally thought to be extragalactic, and the views expressed by Lindsay in the 1967 *Yearbook* still hold good,[15] though it is true that some authorities

have different opinions and regard the quasars as either members of our Galaxy or closely beyond. Pulsars are certainly within our own system, whatever may be their true nature.

To comment further would be premature at the moment, particularly as new information may be to hand before this review appears in print. Meantime, astronomers, both optical and radio, are doing all they can to solve at least some of the problems of these strange objects. No doubt much will be gained from the use of the huge new radio telescope to be set up at Jodrell Bank in the 1970's. The decision to build this instrument was announced by Professor Sir Bernard Lovell in the spring of 1968; things have certainly changed since the building of the famous 250-foot paraboloid, which, as Sir Bernard has related[16] in his recent book, was so plagued by financial troubles until it had been actually brought into operation!

All these investigations are so fundamental that it may be something of an anti-climax to turn back to our Solar System, which is, after all, a very local area. Moreover, there have been no spectacular man-in-space developments during the period under review, though the vast American Saturn-5 rocket, to be used in the Apollo lunar landing programme, has been successfully tested. The effects of the disasters of 1967, involving the three U.S. astronauts at Cape Kennedy and the tragic flight of Colonel Komarov in *Soyuz*-1, are still being felt, though both teams still hope to reach the Moon some time during 1969. On the other hand there were tremendous successes with the two unmanned probes to Venus. In October 1967 Mariner-5 by-passed the planet and sent back confirmation of the high temperature there; on October 18, a few days before the closest approach of Mariner-5, the Russians managed a soft landing on Venus with their first successful interplanetary probe, Venus-4. Signals were received from the instrument capsule as it parachuted down through the planet's atmosphere, and were clearly recorded both in the U.S.S.R. and at Jodrell Bank. This was a major triumph, and showed that the Russians have overcome the communications troubles which negatived all their earlier long-range probes.

From all the evidence, Venus really does have a surface temperature which is hopelessly high for our sort of life. Moreover, the atmosphere seems to be between 15 and 22 times as dense as ours, so that the results would be most peculiar from the viewpoint of any astronaut able to land there; light-rays would be bent, and one American scientist even suggested that a spaceman who looked straight ahead of him would simply see the back of his neck! This may be extreme, but that Venus is a strange, hostile world can hardly be gainsaid.

In June 1968 there was considerable interest on account of the approach of the dwarf asteroid Icarus, a mere half-mile in diameter, which by-passed us at a mere 4,000,000 miles, travelling from Ursa Minor down to Libra in only a few days. It was, of course, a very faint object, but was recovered on schedule by Miss Elizabeth Roemer in Arizona, and was well followed. Icarus is notable because it is the only asteroid known to pass within the orbit of Mercury, so that near perihelion it must be intensely heated. There had been sensational, though quite unfounded, reports (emanating from Australia) that Icarus might hit us, but fortunately there was never any danger of such a catastrophe; Icarus can never come within 4,000,000 miles, and can hardly be regarded as a true 'Earth-grazer'.

In passing, the early summer of 1968 saw the death of one very familiar object, the U.S. balloon satellite Echo I, which – it was claimed – had been seen by more people than was the case with any other man-made object, not excluding Big Ben or the Statue of Liberty! Echo I at last came back into the atmosphere, and decayed. However, Echo II remains in orbit, and is in no imminent danger, though it will not last indefinitely.

All the investigations described here have been strictly professional, but in a Yearbook designed largely for amateur use it may not be out of place to end with a note about a proposed new amateur organization. In 1967 the International Astronomical Union met at Prague, and during the meeting a provisional committee was set up to study the possibilities of founding an organization to correlate useful amateur observational work all

over the world. Matters have developed satisfactorily, and a first Congress has been arranged for the spring of 1969; it will be held at Bologna, in Italy, by the kind invitation of the Italian Astronomical Society and the Bologna City Council. Preliminary details have already been published,[17] and it is hoped that fruitful results will emerge.

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PART THREE

For the Practical Observer

In this issue of the *Yearbook* there has been a departure from normal practice, and three articles are given, covering various topics which will be of interest to the amateur who is anxious to do something more than read about the stars from the depths of his armchair. T. J. C. A. Moseley gives a general introduction to observation, pointing out some of the useful work which may be done. Henry Brinton describes the procedure for taking astronomical photographs, and James Muirden ranges over the sky as seen with binoculars, pointing out some of the many fascinating objects available. Finally, there are lists of interesting variable stars, doubles, and clusters and nebulæ.

First Steps in Amateur Astronomy

T. J. C. A. MOSELEY

This article is intended for the person who is interested in astronomy, and wants to do more than sit in a chair and read about it, but doesn't know what he can do, or where to start. Its scope is only introductory, in that, in the space available, it is not possible to go into details about the topics covered, but it is hoped that the bibliography will take the interested reader as far as he wishes to go.

It is often said nowadays that the day of the amateur astronomer is over: this is simply not so, though it is true that his scope is becoming more restricted, due to increasing professional interest in some of the fields that he long regarded as his own. However, there are still many areas where he can do valuable work, as well as providing himself with a source of intense personal enjoyment.

The first step is to join an amateur organization – the British Astronomical Association (B.A.A.) is undoubtedly the best in Great Britain. This will both facilitate many fields of observation by providing him with information which would otherwise be unavailable, and it also makes his work much more valuable by combining it with other observers' and subjecting it to expert analysis and publication.

The traditional fields in which amateur work has been done are: the Sun, Moon, the planets out to Saturn, meteors, comets, auroræ, artificial satellites and variable stars. In some of these, especially the first two, he cannot really compete with the professional, but the subject will be covered here if only because one has to start one's observational career somewhere, and the skills and knowledge derived therefrom will serve as a useful basis for further, perhaps different, work.

There are certain basic rules for all observational recording; if these are neglected the work immediately loses most, if not all, of its value, and can often be actually harmful.

Any observation should include: the name of the observer; the place of observation (latitude and longitude or Grid reference); the time as accurately as possible, stating whether U.T. or G.M.A.T. (never B.S.T.); the size, type and magnification of the instrument used, if any; the condition of the sky, i.e. seeing, haze, moon, clouds, etc.; the reliability of the observation; and notes to explain any important factors not included above.

SUN

Starting with the Sun, the usual introduction is the recording of sunspots and faculæ. To do this, all one needs is a small refractor – say 2 inches to 4 inches – which need not even be equatorially mounted. Faculæ require apertures of from 4 inches to 8 inches to be well seen. Not only is the amateur unlikely to have a refractor larger than about 5 inches, but such a telescope collects rather more heat and light than is necessary, and steps have to be taken to reduce it, so that the more common reflector is preferable here. Even so, there will be too much light, and unless a diagonal is used the mirror is best left unsilvered, which means that the telescope is useless for any other work.

It is very important that one never looks at the Sun directly through any size or kind of telescope, as even a moment's glimpse may do irreparable damage to the eye. One may come across various dark filters which are placed over the eyepiece, and are said to permit safe observation of the Sun, but these should not be used, as they are liable to splinter without warning.

There are only two safe ways of observing the Sun. The first is to use a 10°-angle prism, which allows most of the light to pass through, and only reflects a small amount to the eyepiece, but these prisms are relatively expensive, and the second method is usually to be preferred. This is to project the Sun's image on to a sheet of white paper held at distance of about 8–20 inches behind the eyepiece, depending on the telescope and the eyepiece.

It is fairly easy to rig up a framework to hold the paper, while a screen fixed over the eyepiece end of the telscope will cut down a lot of the stray light. Even better is a closed box with a window in the side, which will give a darker background and enable a higher magnification to be used. Trial and error will determine the best distance for the paper, and one can then prepare a series of outlines which will fit the size of the Sun's image, with such details as position angle of the Sun's axis of rotation and the heliographic longitude and latitude of the centre of the disk, which can be obtained from various ephemerides, such as the B.A.A. Handbook, or the Astronomical Ephemeris (A.E.). These are essential to reduce the observations so that they refer to the Sun itself, and not simply to its aspect from the Earth. Projection will also reveal the prominences, which are usually found near spots, and are best seen near the limb, which is considerably darker than the centre of the disk. Drawings should be made of any interesting or complex groups.

If the observer regularly records the number and latitude of the spots he will reveal the semi-regular 11-year period between maxima, and also the regular shift from the poles towards the equator with the progress of each cycle, technically known as Spörer's Law, but more popularly as the 'butterfly effect' from the appearance of a graph of the spots' latitude against date. Spots are rarely recorded beyond a latitude of 50°, or within 5° of the equator.

There is a fairly high correlation between sunspot activity, auroræ and terrestrial magnetic storms, and spots can therefore be used as a rough predictor of these events, though the method is by no means infallible.

The observer may be lucky enough to see a solar flare, but this is largely a matter of luck; if one is seen, however, it should be reported to the director of the Radio Astronomy section of the B.A.A., or to Greenwich Observatory.

More advanced work includes high-resolution photography of the spots, which requires a moderate-sized driven telescope; and the recording of prominences by means of a spectroscope, and

flocculi using a spectro-heliograph, both of which are however being done extensively by professionals, and the average amateur is unlikely to be able to equip himself well enough to compete with them. Further information can be found in the list of literature at the end of the article.

MOON

The Moon was until recently largely the exclusive domain of the amateur. With the coming of the space age, however, the professionals have been turning their more powerful and sophisticated equipment towards it, and the amateur has had to turn to certain specialized areas of research to stay in business.

As the 'Orbiters' have now covered the whole surface with their very high-resolution photographs the recording of surface details is now frankly a waste of time, with the possible exception of such features as domes, which require special illumination to show up at all.

The only definitely useful activity left is the observation of Transient Lunar Phenomena, or TLPs. These take the form of minor glows, brief flashes or local obscurations, usually of fairly short duration, though one area may be active for up to a few days. The minimum requirement is a telescope of at least 6-inch aperture, but an 8-inch or 10-inch is better. Some of the phenomena, chiefly the flashes and obscurations, are best seen with the eye alone, but the red glows can often be best shown by means of a device known as a 'Moon-blink'. This consists of a holder which enables one to rotate several filters between the O.G. and the eyepiece, usually just in front of the latter. The glows are of a distinct reddish colour, so that if one is viewed through red and blue filters alternately it will show up as a blinking spot. It is best to leave one section of the filter-disk blank, as this saves one removing the device to obtain a normal view.

Obviously, the whole disk should be observed to determine as many active sites as possible, but if the observer has not time for this he can regularly check the known active areas – Plato, Alphonsus, Aristarchus and the 'Cobra-head', and Gassendi are

the most rewarding areas for this. There are also several areas which give a permanent blink: lists of these, and of all the suspected areas can be found in the literature.

Quite often, a more prominent TLP can be seen without the blink, especially with a large telescope, so the blink device is not absolutely necessary, but when using a refractor one must beware of the false colour inherent in such an instrument.

Obscurations, as the name suggests, take the form of local dimming or blurring of details, while the surrounding areas are quite sharp and clear – Plato seems to be the most active crater here. The flashes are so short and relatively rare that, though there are many individual reports there are no cases of one having been definitely confirmed by another observer.

Except for the flashes, where the data is insufficient, it is found that the distribution is not random – both glows and obscurations are associated with clefts and cleft-ridden craters, especially round the edges of the maria, and none has yet been reported in the South-West (classical sense) quadrant of the Moon.

It has been attempted to correlate the times of activity with solar activity, but this has not been very successful, and it seems that they are in a very broad sense 'volcanic', as they have been found to occur more often at perigee and apogee.

Lunar domes are very low elevations of the surface, usually round or elliptical in shape, requiring a very low angle of illumination to be well seen. There are probably quite a few still undiscovered, but these will be beyond the range of a smallish telescope, and the person just starting lunar observation is unlikely to be able to contribute much in this field.Possibly a more fruitful programme is the 'Project Moonhole' of the B.A.A. Lunar section. This is intended to reveal the different types of interior profiles of the smaller craters.

Most of the craters can be satisfactorily observed with a 4-inch refractor or a 6-inch reflector, while an 8-inch is enough to cover all the craters on the programme. All one has to do is to make a brief sketch of the crater showing the extent and shape of the shadow as accurately as possible: the sketch is then measured

afterwards, as an estimate from the eyepiece is not reliable enough. The craters should be measured on as many occasions as possible, trying to obtain as many estimates after Full Moon as before. The observations should be sent to the B.A.A. where they are being analysed by a computer.

It is not certain how valuable this programme will be, as it has been shown that most observations are not very accurate, and preliminary results from the computer show a large scatter, especially for some craters; but the programme is not completed yet and premature criticism is unjust – the proof will be in the results.

In view of the restriction on other areas of lunar observation, increasing emphasis has been laid recently on the observation of occultations of stars. This requires a telescope of at least 4-inch aperture, and a stop-watch accurate to at least a tenth of a second, while a convenient means of checking with some accurate time signal, such as the G.P.O. speaking clock, or the B.B.C. Greenwich 'Pips' is also necessary. To be properly done, this activity should be carried out in co-operation with a team of observers – once again the B.A.A. is probably the best organization for this.

MERCURY

While posing some intriguing problems for the astronomer, Mercury can be dismissed fairly briefly as far as the inexperienced amateur is concerned. It has a small disk, and is never observable in a dark sky in this country, so that a refractor is preferable to a reflector. It takes a large telescope to show any detail on its disk, and the average amateur's equipment will show the phases and little else. It would be interesting to see if the Schröter Effect occurs on Mercury as well as Venus, and a 6-inch telescope or larger might be usefully employed on this: briefly, it is found on Venus that the observed and theoretical dates of dichotomy (first and last 'quarter') do not coincide.

Other effects observed on Venus, such as the Ashen Light and the cusp caps, may occur on Mercury, but they would be very difficult to observe without a large aperture, especially from Britain.

VENUS

Though much easier to observe, being best seen in daylight or twilight, Venus is almost equally unrewarding, as the dense cloudy atmosphere shows only faint short-lived markings which have so far told us absolutely nothing about the planet, except that they exist. The Schröter effect has been shown unquestionably to operate, and it is doubtful if further observation will reveal any more than we already know.

The Ashen Light, or visibility of the unilluminated hemisphere of Venus, is still a controversial subject, and observers with a reasonable aperture and good east and west horizons (as obviously this observation has to be made against a dark sky) could do useful work by recording the times and extent of visibility of this phenomenon.

The cusp caps have yet to be satisfactorily explained, and a moderate telescope will show them quite well: perhaps more complete observation of their occurrence will yield an explanation.

MARS

Mars is perhaps the most interesting planet in the Solar System, due to the possibility of its harbouring some form of life, but once again the amateur's contribution has been overshadowed by the professional work. This is mainly because a very large telescope is needed to show any real detail except for a few weeks on either side of a favourable opposition, of which there are only two or three every 15 to 17 years. To make matters worse, when at a close opposition, Mars has a high southerly declination, and cannot be well seen from above 40°N latitude.

However, at most oppositions, a telescope of from 6 to 12 inches will enable the observer to record the growth and decline of the polar caps, any major changes in the appearance of the surface features, which do sometimes occur, and to follow any of the white or yellow clouds which drift in the planet's rarefied atmosphere. Clouds may be revealed by the obscuration or paleness of some well-known dark feature, or they may be obvious as such.

It has been suggested that the melting of the polar caps releases

moisture which accounts for the changes observed in the dark areas on the disk. This does not necessarily assume that they are organic – hygroscopic salts have been suggested as an alternative – but there are good reasons for assuming that they are some form of primitive vegetation, so that the problem is of considerable importance and interest.

The usual procedure is to do a drawing on a scale of about 2 inches to the planet's diameter, having beforehand prepared an outline disk showing the phase, and the position and tilt of the poles, these details being obtainable from the B.A.A. Handbook or the A.E. The drawing should be accompanied by descriptive notes, especially if the observer is not a good draughtsman.

The best method for any planetary drawing or recording is to scrutinize the disk for some time, until all the visible detail has been seen. Then sketch in the main features roughly, record the time to the nearest minute, and then fill in the details. As Mars rotates on its axis in about 24½ hours, not more than about 30 minutes should be spent on one sketch, as the changing aspect of the disk will render the details added last incompatible with the first view. Obviously one should start with the preceding area of the disk, as this will disappear soonest due to the rotation.

If one has a micrometer attached to a moderate telescope, useful work can be done by measuring the position angle of the polar cap, which does not always coincide with the pole of rotation. This instrument can also be used in experienced hands to record accurately the drift of clouds over the surface.

JUPITER

This is the most rewarding of the planets as far as observation is concerned, as there is always plenty of constantly changing interesting detail on the disk. In addition, it comes to opposition every 13 months, and presents such a large disk that even a 2-inch refractor will reveal the belts and zones. However, a 4-inch is the useful minimum, and a 6-inch is better.

The basic work for any observer is the taking of transits: that is to say, timing each discernible feature as it is carried over the

central meridian, which is the line joining the N and S poles, by the planet's rotation. As Jupiter turns on its axis in just under 10 hours, the motion of the features over only a few minutes is quite discernible, and with practice the observer should rarely make an error of more than 2 minutes. The procedure is to give a brief identifying description of each feature, and the time of transit to the nearest minute.

For example:	(Fictitious example)	
1968 Jan. 22. 10″ O.G. ×255. seeing fair.	$\lambda 1$	$\lambda 2$
21·38 U.T. white spot in S. Temp. Zone.	—	34·0°
21·40 U.T. projection and filament from N.E.B.s	322·6°	—
21·50 U.T. dark streak in N. Trop. Zone S.	—	41·3°

The longitudes of the features can then be calculated from tables given in the B.A.A.H. and the A.E., as shown in the right-hand columns above. The two longitude systems refer respectively to the equatorial region, and all the rest of the planet, as the two areas have slightly different periods.

The observations should be sent to the Jupiter section of the B.A.A., where all the observations are co-ordinated, and the rotation periods for the different latitudes, and different features such as the famous Red Spot, are derived, and the life-history of each feature is revealed.

Disk drawings should be done occasionally to show the general aspect of the planet, following the same procedure as for Mars, only working more quickly, as Jupiter rotates so much faster. Strip sketches should also be done to show interesting detail in a particular latitude. It is important to remember to allow for the flattening of the disk when preparing an outline disk – probably the easiest thing is to get some printed.

If equipped with a moderate equatorially driven telescope and a micrometer, the observer can do useful work in measuring the changes in latitude of the belts and the Red Spot.

Valuable work can be done with even a 3-inch refractor, however, in timing the beginnings and ends of the satellite eclipses,

which occur quite frequently, as there is a definite discrepancy between theory and observation here. The transits and shadow transits of the satellites are fascinating to watch, but are not quite so valuable. Rarer and most important of all are the mutual satellite phenomena, which occur every 6 or 7 years, but unfortunately the next series is not due till 1973–4.

SATURN

This planet is undoubtedly the most beautiful object in the sky with a moderate telescope. A smaller instrument, below 6-inch, say, will show the rings and most of the satellites, but is not much use except for estimating the magnitudes of the satellites, which seem to be subject to variations, and for estimation of the intensities of the more prominent belts.

Routine work consists of the following:

Appearance and intensity of the belts and zones on the disk, and in particular, transiting any visible surface features, in the same way as for Jupiter. As we know comparatively little about the rotation periods of the different latitudes this is important, but transitable features are depressingly rare.

Shape of the shadows of the rings on the globe, and the globe on the rings, and their intensities.

Visibility and regularity of the Crêpe Ring; visibility of any faint ring outside Ring A; position and width of any minor divisions in the rings apart from Cassini's division.

Occultations of brightish stars by the planet or the rings.

Intensity estimates should be made on the scale of 0 (brightest) to 10 (darkest), with two fixed standards – '1' for the brightness of the outer part of Ring B adjoining Cassini's division in the ansæ, and '10' for a very dark sky or deep black shadow.

Faint divisions in the rings are best measured with a micrometer, but if this is impossible, an accurate sketch should be made, and measured afterwards. Really good seeing is necessary, and a reasonable aperture preferable, if these reports are to be reliable.

Occultations of stars, especially by the rings, are rare and very

important, as they give valuable information about the density of the rings and atmosphere, and the existence of minor ring divisions.

Every 15 years or so the Sun and Earth pass through the ring-plane, so that the rings appear edge-on. These occasions provide opportunities for very useful work, but as the next passage is not due till 1979–80 no more need be said here!

The periods when the rings are edge-on are the best for observing the faint inner satellites, but a moderate telescope will usually reveal all except Janus, Mimas and Phœbe. Estimates of the magnitudes are difficult due to the lack of suitable comparison stars, but one can make do by taking Titan to be constant at 8·3m., and estimating from there. The same procedure as for variable stars is adopted (see below), but one must allow for the satellite's distance from Saturn, as the glare will tend to dim it considerably. To those who say that the amateur's day is over it may be noted in passing that Patrick Moore and the author both had pre-discovery observations of Janus, discovered by Dollfus in 1966.

COMETS

Observation of comets falls into two distinct classes: searching for them, and observation and photography of those whose position is already known. The former is probably the least rewarding, in terms of immediate results, of all types of observations, as one may sweep the skies for several years without discovering anything, but when one does the results are certainly worth the effort as the comet is given the name of its discoverer, apart from the scientific value.

Powerful binoculars are quite adequate for this task, as they have a wide field and are light and easy to use compared with a telescope, but it is often best to mount them on a tripod if they are above about 5 pounds in weight. An elbow telescope can also be used here, as it will give much the same results.

Some comet-seekers prefer a short-focus wide-field reflector of from 6–10-inch aperture, as it has greater light-grasp and enables one to catch the comet at a much fainter stage, as well as rendering

moonlight observation possible; but such an instrument requires a much greater knowledge of the sky on the part of the observer, since there will be many faint nebular objects within its range which may be confused with a comet.

Apart from a telescope or binoculars, and considerable patience, the only other requisite is a star atlas which shows the positions of all the nebular objects within range of one's instrument. Norton's will do for a start, as it shows nebulæ and clusters down to about 7m·5, but the serious observer will want something a bit better than this. Atlas Coeli, by A. Bečvář, is probably the best, as it gives stars down to 7m·75, and nebulæ and clusters to 12m·0.

Comets can appear in any part of the sky, but the most likely areas are within about 100° of the Sun, i.e. in the S.W. to N.W. after sunset, and the N.E. to S.E. before sunrise. The method consists simply of sweeping slowly horizontally back and forth, overlapping by at least one quarter of the field on each successive sweep. If a suspicious object is noted, it should be checked against the star atlas and examined with a higher power. If this does not reveal its true nature, it must be carefully watched for at least an hour to see if it moves against the starry background – any such motion means that it is in fact a comet. Assuming it is not among those predicted annually in the B.A.A.H. its position, magnitude and direction of motion should be determined as accurately as possible and these details sent immediately to the director of the B.A.A. comet section, or to Greenwich Observatory.

Searching for periodic comets whose positions are predicted in the B.A.A. Handbook is best done with a large telescope and camera, or a Schmidt, so no more need be said here; but it is always interesting to make visual observations of such a comet, noting such details as size and shape of comæ, brightness of nucleus, shape of tail, etc., and these may be quite useful to the B.A.A. Comet section.

METEORS

Meteor observation will appeal to many in that it requires nothing more than 'Norton' and a fair degree of patience. There are about

a dozen important showers annually, of which details are given in Norton and the B.A.A. Handbook. The observer simply notes as many of the following details about each meteor as possible: time, position of start and end of flight-path, magnitude, speed, colour, existence of a trail after the meteor has disappeared, any noise associated with it, irregularity of path and anything else of interest. If the meteors are so numerous as to render this impossible, the number per interval of, say, each 30 minutes, and if possible the percentage of those above first magnitude should be noted.

Sporadic meteors may occur at any time or place, and the above points should be noted for any above magnitude 0m·0.

The work will be much more valuable if it is done in co-operation with another observer stationed about 20–50 miles away, as this enables the trajectory of each meteor to be calculated, but the identifications have to be very accurate for this.

Photography will not reveal as many meteors as the naked eye, but it is superior in that the records are more accurate and permanent. A fast film and a fast lens with as wide a field as possible are required; perhaps the best available to the amateur are aerial camera lenses.

The most valuable work of all is in the field of spectrography, but this requires such patience and skill that those who are interested will have to check more advanced sources than this article can cover.

AURORÆ

These are best seen from the north of the British Isles, and town lights will drown all but the brightest. Once again, photography has its place here, requiring much the same conditions as for meteors, only with a faster lens, but the eye has definite advantages in the recording of rapid fluctuations. The observer must learn how to recognize the various forms, and how to estimate brightness and altitude quickly, recording the times and natures of such changes as occur, but no other skill or equipment is needed, and the work can be quite valuable in studies of the Earth's magnetic field. As in the case of meteors, the observations

should be sent to the director of the appropriate section of the B.A.A.

SATELLITES

Artificial satellites form a useful study for those with little time available, or those troubled by artificial lights. Preliminary work can be done with the naked eye, but for accurate results binoculars or an elbow telescope are necessary. One also needs a stop-watch accurate to at least 0·2 seconds, and an atlas such as Norton, or preferably, Atlas Coeli. It should also be possible to obtain an accurate time signal within not more than 20 minutes of each observation – the G.P.O. speaking clock or the B.B.C. radio time signals suffice.

The basic procedure is to record the satellite's position relative to an identifiable star pattern at a precise moment with the stop-watch, and then check against a time signal. Predictions of satellite passages are issued by the Artificial Satellite section of the B.A.A., to which the observations, giving the position of the observer, and the time and position of the satellite, should be sent.

VARIABLE STARS

Moving for the first and only time outside the Solar System, one of the most interesting and rewarding fields is that of variable star observation. There are so many different types that it is not possible to give details of them all here, but those which the amateur observer will be concerned with are the long period variables, such as Mira; irregulars such as Betelgeux; eruptive variables such as SS Cygni, R Coronæ Borealis stars, which are in a class by themselves, and novæ.

About a dozen can be observed with the naked eye, though these are mainly confined to the irregulars; there are scores of all the above types except eruptives within range of good binoculars, and an 8- or 10-inch telescope will cover more stars than any one person can hope to observe.

The basic procedure is simple, though there are many pitfalls for the unwary. One starts off by equipping oneself with a chart

showing the position of the variable, together with a sequence of nearby stars whose magnitudes are accurately known: these are obtainable from the B.A.A. variable star section. The observer then compares the variable with those stars in the sequence which are closest to it in position and magnitude, choosing comparisons both brighter and fainter than the variable. There are several methods and various refinements, details of which can be had from the literature.

By plotting magnitude against time on a graph the observer can see the results of his own work, but as always, it will be much more valuable if combined with other observers', and observations should be sent to the B.A.A. Variable Star Section Director.

An activity akin to comet-hunting, and one often combined with it, is nova hunting. Much the same requirements and rules apply as for comets, except that one needs a thorough knowledge of the sky down to at least the sixth magnitude, and even more patience, as novæ are much rarer than comets. Any find should be immediately reported to Greenwich Observatory and the Director of the B.A.A. Variable Star Section.

Anyone interested to any degree in astronomy will have his interest and knowledge vastly increased by taking up one or more of the activities outlined above, and he will also have the satisfaction that he is contributing work of genuine scientific value.

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Photography at the Telescope

HENRY BRINTON

In recent years, amateur photography with the telescope has been robbed of some of its purpose, though nothing can rob it of its pleasure. Until quite lately, the Moon and the planets were largely the sphere in which the amateur could compete on something like equal terms with the professional. The large observatory instrument is vastly superior for more distant objects because of its capacity for gathering light. The Palomar telescope has getting on for a thousand times the capacity of a fair-sized amateur's.

For purposes of photographing the nearer objects in space, however, the limitation is imposed more by the turbulence of the atmosphere than by the power of light gathering. A 12-inch Newtonian, sited in a space vehicle, and so free from the disturbance of our semi-opaque atmospheric envelope, would take better pictures of the Moon than many a large observatory telescope. Many of the best photographs of the Moon and planets were taken by amateurs. Even so indifferent a performer as I am has taken a photograph of the crater Clavius which, without a second or third look, is not manifestly inferior to that taken by the Palomar giant.

Probes, however, have now been regularly to the Moon and relayed back splendid photographs taken from various distances down to a few feet. Before too long, we shall doubtless have pictures from all the planets, and there will be no scope left for useful, as opposed to interesting amateur photographs. The field, however, is not entirely closed. Amateurs can still keep a constant photographic watch, for instance, for transitory phenomena. On the Moon, there have been many reports of short-lived colour

changes. It remains for one of them to be recorded photographically. There are other fields, too, still open, for example in recording meteors. Apart from these restricted uses, and the exquisite pleasure to be got from a good photograph in the bafflingly difficult sphere of astro-photography, one needs to bear in mind that the Astronomer Royal of tomorrow may be the schoolboy of today. There are few sciences left in which the non-professional stands, for some purposes, on an almost equal footing with the expert.

So far as astro-photography is concerned, the gap is growing wider all the time, except in the field of the nearer objects. Not only is the giant telescope capable of a light-gathering power which dwarfs the back-garden instrument, but in photographic techniques the sophisticated equipment now available is leaving the traditional methods far behind. The use of image intensifiers and converters can produce images with several hundred times fewer photons than direct recording on a sensitive plate or film. For the nearer objects, however, sophisticated equipment has only a limited advantage.

In astronomy as a whole, as well as in astro-photography, the skill and range of practitioners is enormously varied. It is even possible to get a good deal of entertainment, as well as some marginal usefulness, with a cheap camera, and without a telescope at all. Many beginners start by pointing a box camera at the Pole Star on a clear night, and recording the circular trails of the stars with a long time exposure. This at least has the advantage of proving to oneself that the Earth really does go round!

Rather more usefully, a simple camera pointed at the sky on a dark clear night can record meteor trails. At the time of one of the showers, it will show the radiant – that is, the apparent point from which the shower radiates outward. It will also allow a comparison of the relative brightness of the individual meteors.

Much the same procedure will allow one to record the tracks of the brighter artificial satellites. If the shutter is closed when the satellite is passing through a field of visible stars, and an accurate time is taken with the aid of a stop-watch, a useful fix can be

determined. Given the luck of clear skies, two observers at widely separated points, synchronizing their photographs, can get a very accurate fix.

The next stage requires not only a telescope, but one that is equatorially mounted and fairly accurately driven, though quite a lot can be done without a very expensive camera. For a small-scale photograph of the Moon, all that is necessary is to hold a camera, focused at infinity, against a very low-power eye-piece in the telescope. Even a camera with a fixed focus and an instantaneous shutter speed will produce a recognizable picture, though not a particularly good or interesting one.

A small home-made gadget will extend the scope a long way. All that is required is a sheet of metal bent at right angles, large enough to hold the camera balanced against the eye-piece. On the upright side of the tray, a hole is drilled through which the eye-piece can be screwed, holding the tray and camera in position. With this simple arrangement, using the lenses in both the camera and the eye-piece, some quite good work can be done. For one particular purpose, it is the best arrangement. I myself took some excellent pictures of a lunar eclipse in this way, using colour film. This enabled me to get in the whole disk, which would have been impossible with my expensive and specially adapted camera, which has much too small a field for the purpose. The photograph showed up excellently the brick-red colour of the eclipsed sector of the Moon.

The disadvantage of this simple system, which needs nothing much in the way of special equipment, is that the light has to pass through a whole series of lenses, suffering some loss at each. A further stage in effectiveness is to use a single lens reflex camera with a special lens. In fact, anyone who is nimble with his fingers can make an adequate camera for himself. A ground-glass screen for which a plate can be substituted will do the job. The 'shutter' can consist of a simple disk slid by hand over the bottom end of the draw-tube. At its simplest, the lens can be a mere plano-concave which slides in a tube inside the tube of the eye-piece.

The concave lens is adjusted to be inside the focal point, and

will throw back an enlarged image on the plate. By a series of adjustments, the degree of enlargement can be varied at will, though there is a practical limit. This set-up is quite satisfactory for lunar photography, and can do reasonably well with the larger planets.

A better, and not much more expensive arrangement, is to substitute a compound convex lens. The lens of an 8-mm ciné camera serves the purpose well. This is fitted in a similar sliding tube, though, naturally, it is so arranged that it is just outside the focal point, acting more or less like the lens of a projector and throwing an enlarged image on the film. If a bought camera is used, it needs to be adapted to screw into the R.A.S. thread on the inside of the draw-tube, which normally takes the eye-piece. Since the camera lens is not required, a light but sturdy single-lens reflex body need not be expensive.

The lens used, whether it be a ciné lens or something else, should be of about $\frac{1}{2}$-inch focal length. According to the distance which it is set from the film in the camera, the magnification will vary, and can usefully be set to enlarge the primary image by anything over about $\times 5$ to perhaps $\times 12$. With a telescope of f/6, this will result in an equivalent focal length of f/30 to f/72. The exact length selected will depend upon personal predilection and the object to be photographed. Some very good astronomers like to work at about f/80 with a fairly fast film, FP3, for instance. I happen to prefer to work with a shorter length, about f/40 and a finer grain film, usually Pan-F. By using a suitable developer, Promicrol, for example, this can be rated at A.S.A. 100. It can be up-rated still further by using the FF/DD development method.

Each operator must work out his own optimum methods, including exposure times; but, in the sort of terms we are discussing, anything from $\frac{1}{4}$ second to 1 second will probably suffice for the Moon. At least twice the exposure will be needed for Jupiter or Mars, and twice as much again for Saturn. In fact, when trying for that difficult target, it is advisable to use a faster film, accepting the inevitable increase in grain.

Venus offers a target which, in many ways, is easier than the

other planets for a beginner. If for no other reason, the exposure wanted is only in the order of 1/30 second. I have seen good photographs taken at my own telescope by a visitor merely putting his camera against the eye-piece. Another advantage for the beginner is that the photography is best done in broad daylight. I have one which I took when the phase was only 0·1, and Venus so close to the Sun that I did not dare to use the sighting telescope to find it. Naturally, it requires circles, or a good deal of luck to pick the planet up. There is also the drawback that atmospheric turbulence is often highly obtrusive; but patience and luck will, in time, give even a tyro the opportunity for some very satisfactory pictures.

Perhaps the most difficult target for the amateur among the nearer planets is Mercury. The trouble is that it is not bright enough to pick up in the middle of the day with anything less than an 18-inch mirror. And, as it is at best always close to the Sun, this means trying when the planet is low on the horizon, with the consequent shimmering. I have only once managed to get a photograph, though that was in colour, in which the shape of the disk and the phase were at all recognizable – and that gave me a feeling of accomplishment!

The other main target for photography with a telescope is the elusive comet. For the occasional large comets, visible with the naked eye, the camera and telescope exchange rôles. An ordinary camera is fixed to the telescope, and the latter is used for guiding. Since comets of this order are moving against the stellar background, the drive mechanism is no use except for the major movement. One uses a fairly powerful eye-piece – as powerful as will give a distinct image of the nucleus – and sets it so that this is on a cross-wire. Keeping the nucleus on the cross-wire by constant minor adjustments of the R.A. and Declination will keep the camera steadily on the comet, and minor jumps in the movement will not show on the lesser image on the film. The process is lengthy; probably at least an hour's hand guiding will be called for – and it will seem like a lifetime. On the other hand, a good photograph of a comet is a highly satisfactory achievement.

Solar photography also offers interesting and profitable employment; but the technique is rather different. The reader is referred to W. M. Baxter's book *The Sun and the Amateur Astronomer*, which deals with the subject admirably. The two basic ways of tackling the task are, first by using a diagonal which will take off most of the intense light, and then using a filter with a camera against the telescope lens. Alternatively, one projects the image from the telescope on to a screen, which can be replaced with a plate or film.

For solar photography, a refracting telescope should be used, or the flat will be overheated. A much worse danger is to the eye of the observer. In no circumstances should one look at the Sun through the telescope, unless a Sun diagonal is used with a filter. Even using a dark filter alone, there is always a danger that it will crack when being used, causing certain blindness.

In a short article, it has been possible only to touch on some of the aspects of this fascinating subject. There is, however, plenty of available literature for further guidance. Theory, on the other hand, is easier and more profitable to grasp when one has progressed a little way with practice. Enough, I hope, has been written to make some first experiments possible. After that, it is difficult not to get the urge for better things.

The Binocular Sky

JAMES MUIRDEN

Serious astronomical observation is not confined to the possessors of powerful and expensive telescopes. It is natural for the newcomer to think so, and the advertisements of telescope-manufacturing firms reinforce the misconception; but it is high time that binoculars and similar low-power instruments were acknowledged as observational tools of unique potential. They are not simply a 'poor man's telescope'; they can undertake research impossible with a normal astronomical telescope of 3 or 6 inches aperture.

Binoculars – and under this heading I shall include field- or opera-glasses, as well as the popular ex-government monoculars – have two tremendous advantages: they are extremely portable, and they have a wide field of view. To this may be added their erect image, which simplifies reference to a star map, and their relative cheapness. A pair of 7×50 binoculars (which means that the magnification is $\times 7$, and the objective lenses are 50 mm across) can show stars down to the 9th magnitude and cover an area of sky 9° across. They need cost as little as £10 from a government surplus supplier.

The binocular sky is a fascinating place. Freed from the restrictions of most astronomical telescopes, which rarely show more than 1° of sky and show this upside-down, the binocular observer can range across huge vistas of space with ease and comfort. Within the Solar System, tailed comets like those of 1957 and 1965 are seen to perfection. Beyond it, but still near at hand, open clusters like the Pleiades and Præsepe are far more impressive than when seen in a narrow-field telescope. And ranging farther, the Milky Way resolves itself into a stream of powdered glass, the great star-clouds massing against the sky, the ramifications and

mysterious black 'gaps' clearly seen. The observer who has not swept binoculars across a moonless rural sky in autumn has never seen the true range of the Galaxy.

So far, so good; but what *useful* work can binoculars do? Clearly, their low magnification prohibits them from showing details on the planets or resolving close double stars; but their wide field makes them ideal for the observation of the brighter variable stars, and hunting for novæ. This research is of scientific value, and it clearly puts binoculars into the league of serious astronomical instruments.

Binocular variable stars constitute an enormous field of investigation, and one which has been almost totally neglected by observers. For convenience, a binocular variable can be taken as a star varying roughly within the magnitude 5–7·5 range. At this region of brightness, comparison stars often have to be sought at a distance of some degrees from the variable itself, which means that they lie outside the field of an astronomical telescope. The necessity for swinging the instrument from one star to another inevitably introduces errors into the estimate. Binoculars, which can include both stars in the same field of view, perform much better, and, paradoxical though it may seem, produce more accurate results than more powerful equipment.

The binocular sky contains hundreds of bright variable stars, most of which are almost totally unobserved, and I shall mention the positions of some during our survey of the binocular sky. All are marked on the amateur's essential stand-by, *Norton's Star Atlas*, and their positions are indicated on the maps accompanying this article.

The hunt for novæ, very faint stars which suddenly increase their brightness by many thousands of times, is an exciting field of observation. Professional observatories carry out continuous photographic nova patrols, using wide-field cameras; but inevitable delay in development and examination of the plates means that the quick-witted amateur can carry off the prize. This happened most recently on 1967 July 8, when G. E. D. Alcock, of Peterborough, found a faint nova in Delphinus, hardly noticeable

with the naked eye but spotted as a 'stranger' at once in the binoculars he was using. Alcock's success came after 13 years of patient effort, and it would be patently misleading to suggest that any amateur could make a nova discovery in a matter of weeks; but, while searching the binocular sky for its well-known objects, take a careful look at the brighter stars in each constellation and be on guard for a new one!

Before setting to work, an important reminder. The fact that I have singled out relatively few objects is due to lack of space, not to lack of worthiness. The objects below should be treated as the plums in an already rich cake. When observing a constellation, do not simply 'knock off' the listed objects. Seated comfortably in a deck-chair, settle back and examine minutely every field of view in the group. Let nothing escape your notice. Spend an hour, or an evening if need be, on one constellation – there is plenty of time! In this way you will 'discover' things for yourself, and treble your satisfaction.

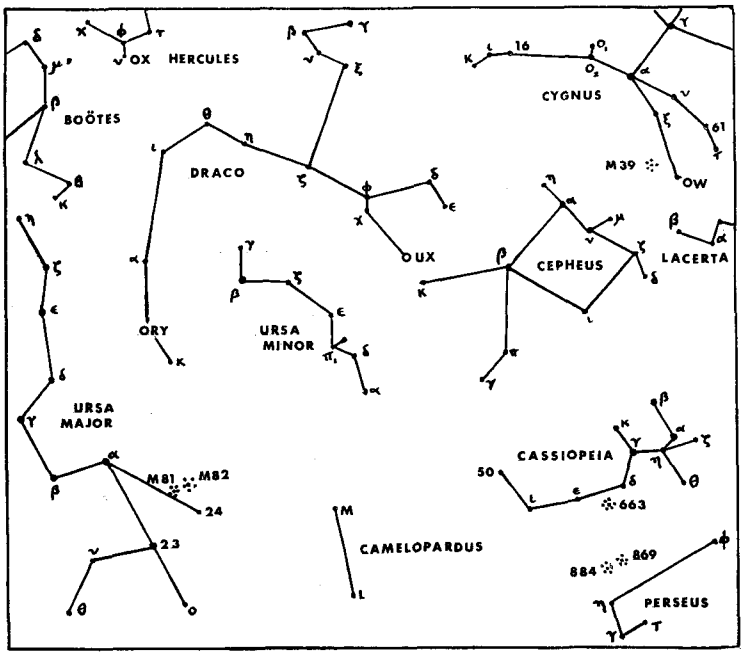
SPRING

The spring sky is relatively barren; the Milky Way lies along the northern horizon, but the Great Bear (Ursa Major) rides high in the sky (Map I). The star Zeta, which is known as *Mizar*, is a good test of atmospheric clarity, for a faint companion, *Alcor*, should be seen very close to it; if not, binoculars will give a clear view. Careful scrutiny should show a star of magnitude 8 lying between *Mizar* and *Alcor*. If the sky is clear enough to show this star, take a look near the star 24, where two tiny gleams of light mark the external galaxies M81 and M82. Ursa Major also contains an interesting irregular variable star, Z, which fluctuates between the 5th and the 8th magnitudes. Another irregular, RY Draconis (mag. 6–8) lies nearby, while UX Draconis (mag. 6–7) lies on the other side of the Pole Star, not far from Kappa Cephei.

Ursa Minor (Map I) has a pair of stars, Pi_1 and Pi_2, near Eta and Zeta. Pi_1, the northern of the two, is a good test for binoculars (6·1, 7·0; 31″). This being successful, Mu in Boötes (Maps I and III) should offer no difficulty (4·0, 6·7; 108″). The nearby Delta is

a much harder test (3·2, 7·4; 105″) for the bright yellow primary obscures the companion. The variable W (mag. 5–6, irregular) is rather difficult to follow, for it is masked by the nearby Epsilon.

The nearby group of Canes Venatici (Map II) contains M3, a



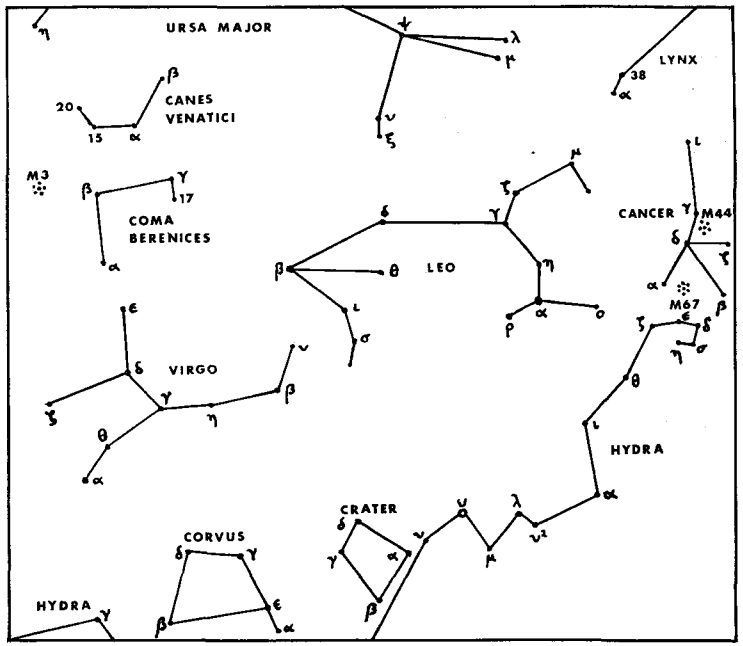
Map I.

bright globular cluster visible in binoculars as a tiny spot. 15 Canum Venaticorum is an easy binocular double (5·5, 6·0; 290″), and 17 Comæ (Map II), near Gamma, is also wide (4·8, 6·0; 145″).

Apart from Ursa Major, Leo (Map II) is the most distinctive spring constellation, and it acts as a guide to the fainter groups. However, it contains little for binoculars. Alpha is a wide, unequal

double (1·3, 8·5; 180″), while Tau is a pretty pair (5·5, 7·0; 90″), the brighter star being yellowish.

The obscure but interesting constellation of Cancer (Map II) lies in front of the Lion's nose. Here are two binocular clusters: M44 or *Præsepe* (the Beehive) is a coarse swarm of bright stars,



Map II.

visible with the naked eye, while M67, west of Alpha, appears as a nebulous spot. Cancer also contains an interesting variable, X, lying east of Delta. The variation is from mag. 6–7, and there may be a rough period of about 200 days, but a series of binocular estimates would be helpful in improving our knowledge of this star.

SUMMER

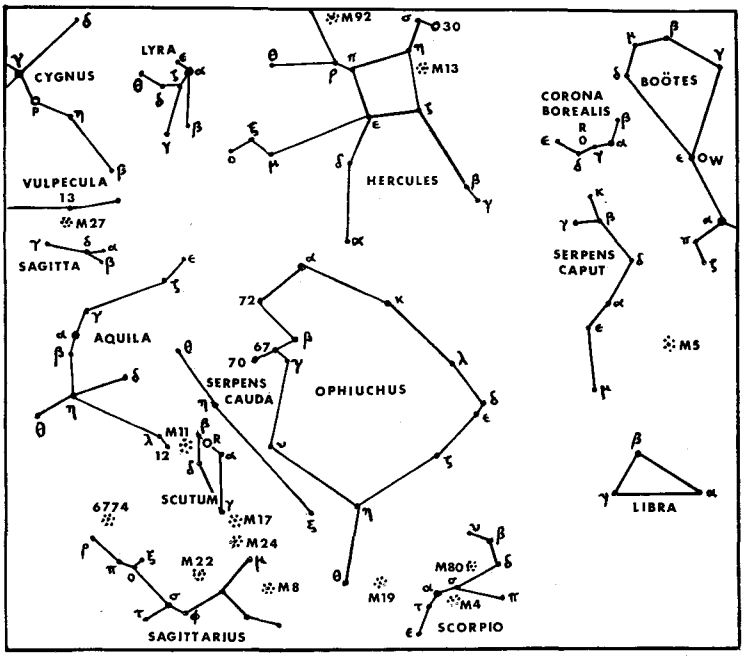
Lyra (Map III) is a well-known summer constellation, for, although small, it is marked by the brilliant blue-white star *Vega*. Lyra lies in a rich part of the Galaxy; spend some time sweeping here with dark-adapted eyes and follow its luminous track down to the southern horizon, through Cygnus, Aquila, Scutum and Sagittarius. But before leaving Lyra look for the binocular pair Zeta (4·0, 5·5; 44″) with tints of orange and blue.

East of Lyra is Cygnus (Maps III and IV), often referred to as the Northern Cross because of its cruciform outline. As well as the splendid Galactic field, there are some interesting binocular objects. The 4th-magnitude star P, for instance, is a nova which flared up in 1600 and has remained near maximum ever since – the slowest nova on record! It is still variable in an irregular way, and is an ideal object for binocular study. W, near Rho, is another irregular of the 5th magnitude, and a fine loose cluster, M39, lies nearby as a guide. Beta Cygni, the famous yellow-and-blue double (3·2, 5·5; 35″) can just be divided with binoculars, and so can the star 16 (5·1, 5·3; 39″).

On the other side of Lyra, in Hercules (Map III) are two globular clusters, M13 and M92. M13 is much the brighter of the two, but even so binoculars cannot begin to resolve it into its thousands of stars. There are also two bright irregular variables: 30 (mag. 4–6) and X (about mag. 6). In the adjacent group of Corona Borealis (Map III) is the fascinating semi-regular variable R, which spends most of its time at about mag. 6, suffering unpredictable falls of up to 6 magnitudes in a few weeks and gradually returning to normal. Binoculars are very useful for timing its maxima.

The small asterism of Vulpecula (Map III), south-east of Cygnus, contains the famous Dumb-bell Nebula, M27, visible in binoculars as a hazy spot; in a large telescope, it bears a distinct resemblance to a cotton-reel! Far more impressive for the binocular observer is the magnificent open cluster M11, in Scutum (Map III), a fan-shaped mass of stars at the nucleus of a superb

Milky Way field. The irregular variable R (mag. 4–7) is nearby. It is a great pity that these dense regions of the Galaxy are so low in the sky to the British observer, who must also observe them during the twilight nights of midsummer; I well remember my amazement at seeing the brilliant star-clouds of Sagittarius glowing forth high



Map III.

above the horizon in the black skies of southern Greece! Amongst a wealth of objects in this constellation (Map III), which contains, from our line of sight, the nucleus of the Galaxy, even binoculars give grand views of the Horseshoe Nebula, M17, the globular cluster M22, and the open cluster NGC 6774. There is also M8, a roughly spherical loose cluster of 9th-magnitude stars, while the region of M24, which itself appears as a faint nebulous patch, is

indescribably magnificent, especially in the direction of Mu, where a great star-cloud is visible with the naked eye.

The nearby southern reaches of Ophiuchus (Map III) contain a few objects for binoculars. Look first at M19, a small, bright, compressed cluster east of *Antares* (Alpha Scorpii). More impressive is the open cluster H.VIII.72, consisting of 8th-magnitude and fainter stars, lying in a superb part of the Milky Way and just detectable with the naked eye under perfect conditions. When surveying this constellation, I was surprised to come across an open cluster of 8th-magnitude stars about 1° N.E. of Beta; it does not seem to be included in any catalogue I have consulted! The star 67 is a test-object for binoculars: 4·6, 8·5; 54″. Take note also of the bright globular cluster M5 in Serpens Caput (Map III) – the head of the Serpent, which lies west of Ophiuchus, its tail (Serpens Cauda) lying to the east.

Following the Milky Way into Scorpio brings us more fine Galactic objects. M80, a compressed cluster, appears as a circular nebulosity, and so does M4, which is brighter and larger, and easily found closely west of Antares. These are wonderful regions for the summer observer!

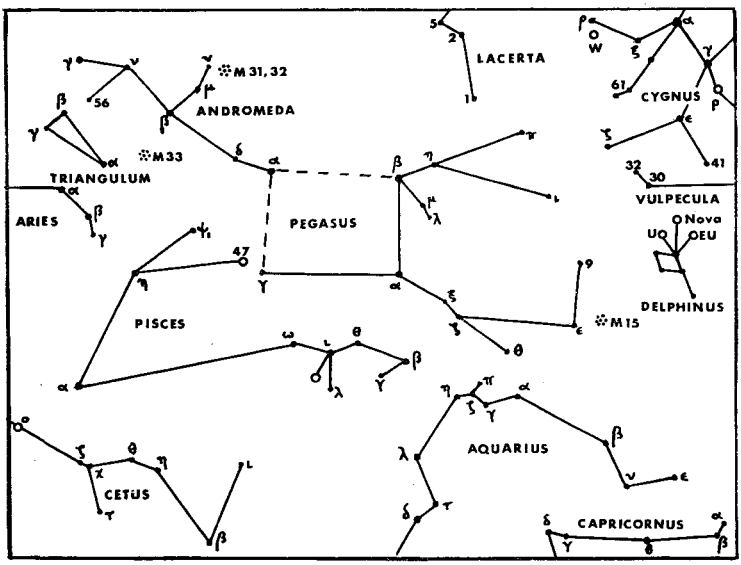
AUTUMN

For the past year, the most intensely-observed constellation in the sky has been the tiny, diamond-shaped asterism of Delphinus (Map IV), sheltering under the eastern wing of Cygnus, for it is here that the nova of 1967 was found. Unlike most novæ, which dim down below naked-eye visibility in a matter of weeks, this one has remained above the 6th magnitude until the time of writing (February 1968), and it may well be detectable with binoculars for a considerable time in the future. Two irregular variables of about the 6th magnitude, U and EU, lie nearby.

The well-known 'W' formation of Cassiopeia (Map I) is high in the sky. This contains fine Milky Way fields, notably around Zeta, but NGC 663 is the only bright cluster. Cepheus (Map I), however, although less obvious to the naked eye, contains rich fields and a number of interesting objects. The star Mu, christened

by William Herschel the Garnet Star because of its rich tint, varies irregularly between the 3rd and 4th magnitudes. Delta is another bright variable, a yellow Cepheid of about the 4th magnitude, with a bluish mag. 7·5 companion at a distance of 41″.

The nearby Andromeda (Map IV) contains one of the most famous objects in the sky, the Andromeda Galaxy (M31), easily



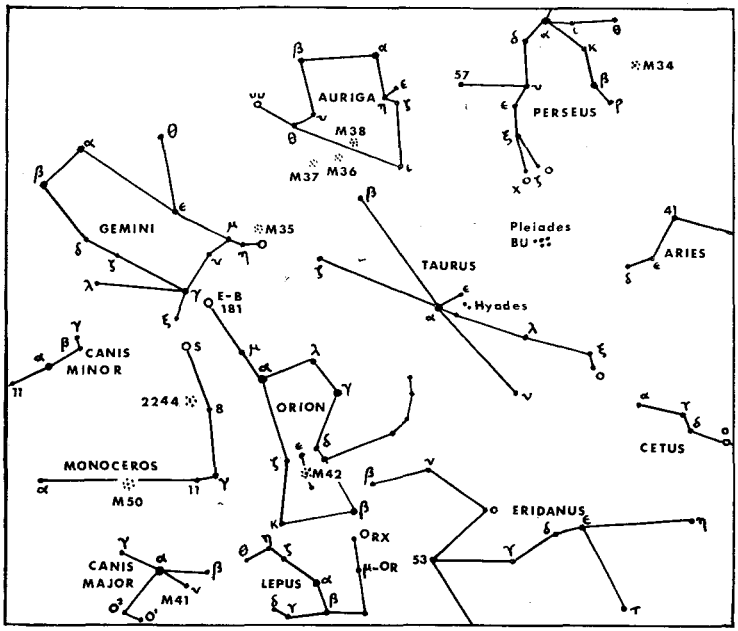
Map IV.

visible with the naked eye. Binoculars reveal it as a misty ellipse measuring about $1\frac{1}{2}° \times \frac{1}{2}°$, and they also show a bright companion galaxy, M32, to the south. Star 56 is an easy pair: 5·8, 6·0; 181″.

South of Andromeda, in the small but conspicuous group of Triangulum (Map IV) is another intriguing galaxy, M33. This, unlike M31, is seen almost 'square-on', so that it appears roughly circular, with a diameter of about $\frac{1}{2}°$; but it is extremely faint and elusive. It is visible with binoculars, and I have seen it with the naked eye, but it is very hard to see with a powerful telescope

because the necessarily higher magnification makes it lose contrast with the sky.

Pegasus, marked by the Great Square formed by Alpha, Beta and Gamma Pegasi and Alpha Andromedæ (Map IV), is dull for its size, although the globular cluster M15 is visible as a pale spot.



Map V.

More interesting, though rather obscure, is the rambling group of Pisces (Map IV), in which the star Psi$_1$ is a close pair (5·6, 5·8; 30″). There are also two bright irregular variables, stars 19 and 47, both of which vary from the 4th to the 5th magnitude.

Cetus (Maps IV and V), like Pisces, is dull to the naked eye; but its star Omicron, better known as *Mira*, is a famous long-period variable which ranges from the 3rd to the 9th magnitude with a period of about 11 months. Its last maximum, at the time of

writing, occurred in 1967 November, and at such times its reddish colour makes it conspicuous with binoculars. The variable T is also well worth watching; it is irregular, varying from mag. 5–7.

Capricornus (Map IV), another low and obscure group, has two wide and bright pairs. Alpha is divisible with the naked eye (3·2, 4·2; 6′ 16″), and Beta is easy with binoculars (3·3, 6·2; 205″), the colours of yellow and blue making it attractive.

WINTER

The winter sky contains a great deal of work for the binocular observer. The bright Milky Way group of Perseus (Maps I and V) is a rich hunting-ground. Half-way between Alpha Persei and Cassiopeia, the naked eye perceives a 'knot' in the silvery stream, and binoculars give a really splendid view of the famous Double Cluster, NGC 869 and 844. These open clusters are magnificent individually; together, they constitute the low-power showpiece of the sky. M34 is a coarser cluster, but still impressive, and the star 57 is a wide double (5·2, 6·2; 113″). Rho is a bright irregular variable (mag. 3–4), and the star X, near Zeta, is a 6th-magnitude irregular.

Auriga (Map V), east of Perseus, is also a rich group. It contains three magnificent open clusters, M36–38, of which M37 is particularly suited to binoculars, while the star UU varies from mag. 5–7 with a very rough period of 10 months. South of Auriga are the naked-eye open clusters in Taurus (Map V), the *Hyades* and the *Pleiades*, well known to every sky-watcher and, because of their large angular size, seen to far better advantage in binoculars than with a regular astronomical telescope. Take note of the naked-eye pair Theta (4·3, 4·6; 5′ 30″) within the Hyades. 28 Tauri, in the Pleiades, varies irregularly from the 4th to the 5th magnitude, and its brightness can be compared with that of other members of the group.

Gemini (Map V) is another rewarding constellation. The star Zeta is a wide pair (4, 7·0; 94″), the primary being a Cepheid variable. Eta is a long-period variable (3·2–4·2, 231 days), and

star 6 is irregular, mag. 6–7. In the same field is the splendid cluster M35, which appears as a large, granular mass.

Observers often tend to overlook Monoceros (Map V), which runs southwards from Gemini alongside Orion. This, undoubtedly, is because of its lack of bright stars, but the Galaxy runs through it and it contains some fine objects, especially for the larger telescope. Binoculars can afford a good glimpse of M50, a bright open cluster, while NGC 2244 is a superb group of bright and faint stars, visible to the naked eye; there are many splendid star fields in this region. Take note also of the bright variable S, which fluctuates irregularly between the 4th and 5th magnitudes.

South of Monoceros, in Canis Major (Map V), the fine open cluster M41 shines just below the brilliant *Sirius*. In Lepus (Map V), to the west, the star Gamma is a wide binocular double (3·8, 6·4; 95″), and the well-known variable R is well worth finding when near its 6th-magnitude maximum for its velvety red hue. There is another very red star closely west of Iota; and this, RX, varies irregularly from mag. 6–7. It is marked in *Norton's* as E-B 120, the letters referring to the famous Espin-Birmingham catalogue of red stars of 1888.

It is hardly necessary to draw even the beginner's attention to M42, the Great Nebula in Orion (Map V); but study the star Iota, and see if a separate nebulosity can be made out here; it is far fainter than M42, but belongs to the Great Nebula. Look also at Delta, a fine binocular pair (2·0, 6·8; 53″). Finally, as an indication of what a small telescope can achieve, turn to the 6th-magnitude star E-B 181, on the constellation's border with Gemini. A friend of mine recently discovered this to be an unrecorded variable star, varying from about mag. 5·6–6·0 – he used a 2-inch aperture telescope with a magnification of ×10! This is just one of many proofs that binoculars and hand-telescopes are not beginners' toys; if used diligently they can, even in these days of great astronomical instruments, make important astronomical discoveries.

Some Interesting Telescopic Variable Stars

Variable star research forms an important branch of observational astronomy, and amateur work is very valuable. The methods were described by J. S. Glasby, Director of the Variable Star Section of the British Astronomical Association, in the 1968 *Yearbook*. The following list of telescopic variables is not exhaustive, but provides plenty of scope for the interested amateur equipped with a modest telescope.

Star	R.A. *h*	*m*	Dec. °	′	*Mag. range*	*Period, days*	*Remarks*
R Andromedæ	0	22	+38	18	6·1–14·9	409	
W Andromedæ	2	14	+44	4	6·7–14·5	397	
R Aquilæ	19	4	+ 8	9	5·7–12·0	300	
R Arietis	2	13	+24	50	7·5–13·7	189	
R Aurigæ	5	13	+53	32	6·7–13·7	459	
R Boötis	14	35	+26	57	6·7–12·8	223	
R Cassiopeiæ	23	56	+51	6	5·5–13·0	431	
T Cassiopeiæ	0	20	+55	31	7·3–12·4	445	
T Cephei	21	9	+68	17	5·4–11·0	390	
Omicron Ceti	2	17	− 3	12	2·0–10·1	331	Mira.
R Coronæ Borealis	15	46	+28	18	5·8–14·8	–	Irregular.
R Cygni	19	35	+50	5	6·5–14·2	426	
U Cygni	20	18	+47	44	6·7–11·4	465	
W Cygni	21	34	+45	9	5·0– 7·6	131	
SS Cygni	21	41	+43	21	8·2–12·1	–	Irregular.
Chi Cygni	19	49	+32	47	3·3–14·2	407	Near Eta.
R Draconis	16	32	+66	52	6·9–13·0	246	
R Geminorum	7	4	+22	47	6·0–14·0	370	
S Herculis	16	50	+15	2	7·0–13·8	307	
R Hydræ	13	27	−23	1	4·0–10·0	386	
R Leonis	9	45	+11	40	5·4–10·5	313	Near 18, 19.
R Leporis	4	57	−14	53	5·9–10·5	432	'Crimson star.'
R Lyncis	6	57	+55	24	7·2–14·0	379	
W Lyræ	18	13	+36	39	7·9–13·0	196	
U Orionis	5	53	+20	10	5·3–12·6	372	
R Pegasi	23	4	+10	16	7·1–13·8	378	
S Persei	2	19	+58	22	7·9–11·1	810	Semi-regular.
R Scuti	18	45	− 5	46	5·0– 8·4	144	
R Serpentis	15	48	+15	17	5·7–14·4	357	
R Ursæ Majoris	10	41	+69	2	6·7–13·4	302	
S Ursæ Majoris	12	42	+61	22	7·4–12·3	226	
T Ursæ Majoris	12	34	+59	46	6·6–13·4	257	
S Virginis	13	30	− 6	56	6·3–13·2	380	
R Vulpeculæ	21	2	+23	38	8·1–12·6	137	

Most of these are long-period variables of the Mira type, very easy with small telescopes when near maximum, but needing large

apertures when near minimum. Chi Cygni is an extreme example. Of course, these long-period stars are not entirely predictable; the magnitude range given here represents the greatest possible – for instance, Mira itself can attain magnitude 2, but at some maxima it never rises much above 4.

There are also some 'awkward' stars which are not easy to study because of a lack of suitable comparisons. R Lyræ is an example of this. Its magnitude range is from 4 to 5, which means that it is always visible to the naked eye, but binoculars are more suitable – provided that their field is large enough to bring in the comparisons, of which the best are Eta Lyræ (mag. 4·5) and 16 Lyræ (5·1). The period of R Lyræ is said to be about 46 days, but this is very arbitrary and uncertain, and is certainly subject to great irregularities. It is not alone of its kind! And with naked-eye variables, such as Betelgeux and Beta Pegasi, allowance must be made for extinction.

Some Interesting Double Stars

The pairs listed below are well-known objects, and all the primaries are easily visible with the naked eye, so that right ascensions and declinations are not given. Most can be seen with a 3-inch refractor, and all with a 4-inch under good conditions, while quite a number can be separated with smaller telescopes, and a few (such as Alpha Capricorni) with the naked eye. Yet other pairs, such as Mizar-Alcor in Ursa Major and Theta Tauri in the Hyades, are regarded as too wide to be regarded as bona-fide doubles!

Name	*Magnitudes*	*Separation,"*	*Position angle, deg.*	*Remarks*
Gamma Andromedæ	3·0, 5·0	9	060	Yellow, blue. B is again double (0".4) but needs a larger telescope.
Zeta Aquarii	4·4, 4·6	2·6	291	Becoming more difficult.
Gamma Arietis	4·2, 4·4	8	000	Very easy.
Theta Aurigæ	2·7, 7·2	3	330	Stiff test for 3 in. OG.
Delta Boötis	3·2, 7·4	105	079	Fixed.
Epsilon Boötis	3·0, 6·3	2·8	340	*Yellow, blue. Fine pair.*
Kappa Boötis	5·1, 7·2	13	237	Easy.
Zeta Cancri	5·6, 6·1	5·6	082	
Iota Cancri	4·4, 6·5	31	307	Easy. Yellow, blue.
Alpha Canum Venat.	3·2, 5·7	20	228	Yellowish, bluish. Easy.
Alpha Capricorni	3·2, 4·2	376	291	Naked-eye pair. Alpha^2 again double.
Eta Cassiopeiæ	3·7, 7·4	11	298	Creamy, bluish. Easy.
Beta Cephei	3·3, 8·0	14	250	
Delta Cephei	var, 7·5	41	192	Very easy.
Xi Cephei	4·7, 6·5	8	270	Reasonably easy.
Gamma Ceti	3·7, 6·2	3	300	*Not too easy.*
Zeta Coronæ Borealis	4·0, 4·9	6·3	304	
Delta Corvi	3·0, 8·5	24	212	
Beta Cygni	3·0, 5·3	35	055	Yellow, green, Glorious.
61 Cygni	5·3, 5·9	25	150	
Gamma Delphini	4·0, 5·0	10	265	Yellow, greenish. Easy.
Nu Draconis	4·6, 4·6	62	312	Naked-eye pair.
Alpha Geminorum	2·0, 2·8	2	151	Castor. Becoming easier.
Delta Geminorum	3·2, 8·2	6·5	120	
Alpha Herculis	var, 6·1	4·5	110	Red, green.
Delta Herculis	3·0, 7·5	11	208	Optical double.
Zeta Herculis	3·0, 6·5	1·4	300	*Fine, rapid binary.*
Gamma Leonis	2·6, 3·8	4·3	121	Binary; period 400 years.
Alpha Lyræ	0·0, 10·5	60	180	Vega. Optical; B faint.
Epsilon Lyræ	4·6, 6·3	3	005	Quadruple. Both pairs
	4·9, 5·2	2·3	111	separable in 3 in. OG.
Zeta Lyræ	4·2, 5·5	44	150	Fixed. Easy double.
Beta Orionis	0·1, 6·7	9·5	205	Rigel. Can be split with 3 in.
Iota Orionis	3·2, 7·3	11	140	

Name	*Magnitudes*	*Separation,"*	*Position angle, deg.*	*Remarks*
Theta Orionis	6·0, 7·0 7·5, 8·0			The famous Trapezium in M.42.
Sigma Orionis	4·0, 7·0 7·5, 10·0	11·1 12·9	236 085	Quadruple. D is rather faint in small apertures.
Zeta Orionis	1·9, 5·0	3	160	
Eta Persei	4·0, 8·5	8·5	300	Yellow, bluish.
Alpha Piscium	4·3, 5·3	1·9	291	
Alpha Scorpii	0·9, 6·8	3	275	Antares. Red, green.
Nu Scorpii	4·2, 6·5	42	336	
Theta Serpentis	4·1, 4·1	23	103	Very easy.
Alpha Tauri	0·8, 11·2	130	032	Aldebaran. Wide, but B is very faint in small telescopes.
Zeta Ursæ Majoris	2·3, 4·2	14·5	150	Mizar. Very easy. Naked-eye pair with Alcor.
Alpha Ursæ Minoris	2·0, 9·0	18·3	217	Polaris. Can be seen with 3 in.
Gamma Virginis	3·6, 3·7	4·8	305	Binary; period 180 yrs. Closing.
Theta Virginis	4·0, 9·0	7	340	Not too easy.

Some Interesting Clusters and Nebulae

Object	R.A.		Dec.		*Remarks*
	h	*m*	°	′	
M.31 Andromedæ	00	40·7	+41	05	Great Galaxy, visible to naked eye.
H.VIII 78 Cassiopeiæ	00	41·3	+61	36	Fine cluster, between Gamma and Kappa Cassiopeiæ.
M.33 Trianguli	01	31·8	+30	28	Spiral. Difficult with small apertures.
H.VI 33–4 Persei	02	18·3	+56	59	Double cluster; Sword-handle.
M.1 Tauri	05	32·3	+22	00	Crab Nebula, near Zeta Tauri.
M.42 Orionis	05	33·4	−05	24	Great Nebula, Contains the famous Trapezium, Theta Orionis.
M.35 Geminorum	06	06·5	+24	21	Open cluster near Eta Geminorum.
H.VII 2 Monocerotis	06	30·7	+04	53	Open cluster, just visible to naked eye.
M.41 Canis Majoris	06	45·5	−20	42	Open cluster, just visible to naked eye.
M.44 Cancri	08	38	+20	07	Præsepe. Open cluster near Delta Cancri. Visible to naked eye.
M.97 Ursæ Majoris	11	12·6	+55	13	Owl Nebula, diameter 3′. Planetary.
M.3 Canum Venaticorum	13	40·6	+28	34	Bright globular.
M.80 Scorpionis	16	14·9	−22	53	Globular, between Antares and Beta Scorpionis.
M.4 Scorpionis	16	21·5	−26	26	Open cluster close to Antares.
M.13 Herculis	16	40	+36	31	Globular. Just visible to naked eye.
M.92 Herculis	17	16·1	+43	11	Globular. Between Iota and Eta Herculis.
M.7 Scorpionis	17	51·6	−34	48	Fine open cluster. Very low in England.
M.23 Sagittarii	17	54·8	−19	01	Open cluster nearly 50′ in diameter.
H.VI 37 Draconis	17	58·6	+66	38	Bright planetary.
M.8 Sagittarii	18	01·4	−24	23	Lagoon Nebula. Gaseous. Just visible with naked eye.
NGC 6572 Ophiuchi	18	10·9	+06	50	Bright planetary, between Beta Ophiuchi and Zeta Aquilæ.
M.17 Sagittarii	18	18·8	−16	12	Omega Nebula. Gaseous. Large and bright.
M.11 Scuti	18	49·0	−06	19	Wild Duck. Bright open cluster.
M.57 Lyræ	18	52·6	+32	59	Ring Nebula. Brightest of planetaries.
M.27 Vulpeculæ	19	58·1	+22	37	Dumb-bell Nebula, near Gamma Sagittæ.
H.IV 1 Aquarii	21	02·1	−11	31	Bright planetary near Nu Aquarii.
M.15 Pegasi	21	28·3	+12	01	Bright globular, near Epsilon Pegasi.
M.39 Cygni	21	31·0	+48	17	Open cluster between Deneb and Alpha Lacertæ. Well seen with low powers.

PART FOUR

Miscellaneous

Some Recent Books

Old and New Astronomy, by E. A. Beet (Bell, 1967). An excellent general introduction, suited both to school-age and older readers.

Life, Mind and Galaxies, by V. A. Firsoff (Oliver & Boyd, 1968). A survey of the problem of life beyond the Earth, with some original contributions by the author.

The Amateur Astronomer's Lunar Photographic Atlas, by Henry Hatfield (Lutterworth, 1968). A full atlas of the Moon, with a long series of first-class photographs covering the entire surface, together with a complete map. The lunar observer will find it invaluable.

Quasars, by F. Kuhn and H. Palmer (Manchester University Press, 1968). A semi-technical but mainly non-mathematical introduction to quasars, excellently written by two leading experts in this field of research.

Suns, Myths and Men, by Patrick Moore (Muller, 1968). An outline of changing views of the universe, with a look into the future, and with some highly controversial opinions.

Essentials of Astronomy, by L. Motz and R. Duveen (Blackie, 1967). A first-class general survey, semi-technical and ideally suited to the serious student and the University undergraduate.

Their Majestié's Astronomers, by C. A. Ronan (Bodley Head,1968). A survey of British astronomy from its beginnings to the present time, written in the author's usual informative style. Highly recommended.

The Penguin Dictionary of Astronomy, by Åke Wallenquist (Penguin, 1968). A useful, concise dictionary of astronomical terms by a leading Swedish astronomer, well translated and well presented.

Our Contributors

D. A. ALLEN, B.A., is a graduate of Cambridge University, and is currently engaged upon research at the University Observatory. In addition to his astrophysical work he is an enthusiastic observer of the Moon, and has published many selenographical papers.

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H. G. MILES, M.Sc., F.R.A.S., is the Director of the Artificial Satellite Section of the British Astronomical Association, and has undertaken much research into satellite orbits; he is also a specialist in meteor astronomy. He is Lecturer in Mathematics at the Lanchester College of Technology, Coventry.

T. J. C. A. MOSELEY, F.R.A.S., lives at Armagh in Northern Ireland, and is currently at Queen's University, Belfast. He is an active observer, chiefly of variable stars and the planet Jupiter. He is on the Council of the Irish Astronomical Society, and is associate editor of the astronomical periodical *Planetarium*.

HENRY BRINTON, F.R.A.S., has a private observatory at Selsey in Sussex. He has been a regular contributor to the *Yearbooks*, and is the author of many books – including social works and novels as well as science – together with research papers. He is well known also for his broadcasting and television. At present much of his time is occupied with his work in connection with the Regional Hospital Board.

JAMES MUIRDEN lives in Wales, and is the author of several books on practical astronomy. He, too, is a regular contributor to the *Yearbook* as well as to other publications.

Astronomical Societies

The advantage of joining an astronomical society are obvious enough. Full information about national and local Societies was given in the 1966 *Yearbook*; a condensed list, suitably brought up to date, is given below.

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
British Astronomical Association	303 Bath Road, Hounslow West, Middlesex (Miss Lydia A. Brown)	45*s* (§30*s*)	Burlington House, Piccadilly Last Wed. each month (Oct-June)
Irish Astronomical Society:			
Belfast Centre	35 Ardenvohr Road, Belfast (D. Beesley)	20*s* (§10*s*)	Fortnightly, Queen's University, Belfast
Dublin Centre	St Fintan's Cottage, Carrickbrack Road, Sutton, County Dublin (F. Murphy)	20*s* (§10*s*)	Fortnightly University College, Earlsfield Terrace, Dublin
Armagh Centre	The Royal School, Armagh (J. Perrott)	20*s* (§5*s*)	Monthly The Planetarium, Armagh
North-West Centre	Magee University College, Londonderry (Professor W. J. Guthrie)		
Junior Astronomical Society	17 Chanctonbury Chase, Redhill, Surrey (D. Beglan)	15*s*	Caxton Hall, London, S.W.1 Quarterly
Altrincham and District Astronomical Society	33 Edale Grove, Sale, Cheshire (F. W. Talbot)	5*s*	Park Road Library, Timperly 3rd Friday of each month
Aylesbury Astronomical Society	9 Elm Close, Butler's Cross, Aylesbury (N. Neale)	20*s*	As arranged
Birmingham Astronomical Society	17 Hannafore Road, Edgbaston, (W. E. Marsh)	20*s* (§5*s*)	Birmingham and Midland Institute Monthly
Bristol Astronomical Society	10 Sherbourne Street, St. George, Bristol 5 (S. J. Brewer)	20*s*	Lecture Theatre, Bristol University 3rd Friday each month, Sept.-May
Caithness and Dounreay Astronomical Society	Room 31, Ormlie Lodge, Thurso, Scotland (Miss M. J. A. Clark)	20*s*	Fortnightly
Cambrian Astronomical Society	43 Heol Chappell, Whitchurch, Cardiff (G. Stokes)	15*s* (§7*s* 6*d*)	Every 3rd week, 7.30. 38 Park Place, Cardiff
Cambridge Astronomical Society	5 Haggis Gap, Fulbourn (S. R. Whistler)	21*s* (§7*s* 6*d*)	7 Brooklands Avenue, Cambridge 2nd Mon. each month, Oct.–July

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Chester Society of Natural Science, Literature and Art	8 Guy Lane, Waverton, nr. Chester (Mrs N. Hoskyns)	—	Grosvenor Museum, Chester Fortnightly
Chesterfield Astronomical Society	10 George Street, Birmingham Chesterfield (Mrs M. E. Garrod)	15*s*	Barnett Observatory, Newbold Each Friday
Clackmannanshire Astronomical Society	9 Deer Park, Sauchie, Alloa (J. Cluckie)	20*s*	St Mary's School, Alloa. Monthly, 3rd Friday Sept.–May
Crawley Astronomical Society	Crawley College of Further Education, Sussex (F. D. Cooper)	7*s* 6*d*	Crawley College of Further Education Monthly
Crayford Manor House Astronomical Society	Manor House Centre, Crayford, Kent (R. H. Chambers)	None	Manor House Centre, Crayford Monthly during term-time
Dundee Astronomical Society	4 Finlaggan Place, Dundee Scotland (D. Gavine)	10*s* (§5*s*)	Mill's Observatory Dundee Fortnightly in the winter
Eastbourne Astronomical Society	80 Ringwood Road, Eastbourne, Sussex (W. O. Tutt)	21*s* (§10*s* 6*d*)	As arranged Monthly
East Lancashire Astronomical Society	95 Accrington Road, Blackburn (L. Willan)	20*s* (§7*s* 6*d*)	Longridge Observatory, Preston
Astronomical Society of Edinburgh	126 W. Saville Terrace, Edinburgh 9, Scotland (N. G. Matthew)	20*s*	Calton Hill Observatory, Edinburgh Monthly
Ewell Astronomical Society	11 Elmwood Drive, Ewell, Surrey (J. Bentley)	20*s* (§10*s*)	Pitt House, Ewell, Surrey 2nd Tuesday of each month
Fellowship of Junior Astronomers, Edinburgh	58 Ogilvie Terrace, Edinburgh 11, Scotland (Miss Edith McLean)	7*s* 6*d*	Calton Hill Observatory, Edinburgh 2nd Sat. each month, Sept.–June
Fylde Astronomical Society	115 Abercrombie Road, Fleetwood, Lancs (P. P. Cuffe)	10*s* (§5*s*)	Nautical College, Fleetwood 1st Thursday of each month, Sept.–May inclusive
Astronomical Society of Glasgow	164 Mugdock Road, Milngavie, Glasgow, Scotland (N. M. Orr)	10*s*	Roy. Coll. Science and Tech., Glasgow 3rd Thur. each month, Sept.–April
Leeds Astronomical Society	Maths. Dept., The University, Leeds 2 (B. L. Meek)	10*s* (§5*s*)	Leeds University Six annually
Leicester Astronomical Society	49 Bringhurst Road, Leicester (C. Shuttlewood)	21*s* (§7*s* 6*d*)	Leicester Museum and Art Gallery Monthly
Lincoln Astronomical Society	344 Brant Road, Lincoln (P. Hammerton)	20*s* (§5*s*)	Lincoln YMCA Hall 1st Tue. each month
Liverpool Astronomical Society	135 St Michael's Road, Great Crosby, Liverpool 23 (J. E. Abrahams)	15*s* (§5*s*)	Royal Institution, Liverpool Monthly

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Maidenhead Astronomy Group	129 Fane Way, Maidenhead, Berkshire (S. A. H. Roper)	10*s* (§2*s* 6*s*)	Maidenhead Grammar School Once every 3 weeks
Manchester Astronomical Society	Cragside, Cliff Avenue, Summerseat, Bury (Alan Whittaker)	20*s* (§10*s*)	Godlee Observatory, Manchester 1 Weekly
Newcastle-on-Tyne Astronomical Society	30 Kew Gardens, Whitley Bay, Northumberland (G. E. Manville)	20*s*	Botany Lecture Theatre Newcastle University Monthly, Sept.–April
Nottingham Astronomical Society	18 Naseby Close, Heathfield, Nottingham (C. Swift)	25*s*	Monthly
Oxshott Astronomical Group	Norman Cottage, Pond Piece, Sheath Lane, Oxshott, Surrey (E. H. Noon)	10*s*	Oxshott Village Centre 1st Wed. each month Sept.–May
Paisley Astronomical Society	14 Cheviot Avenue, Barrhead, Glasgow (Mrs J. Holms)	20*s* (full), 10*s* (associate) (half subscription for those under 21)	Coats Observatory, 49 Oakshaw Street, Paisley Monthly
Plymouth Astronomical Society	5 Woodside, Lipson, Plymouth (Lawrence Harris)		Plymouth College of Technology, Tavistock Road, Plymouth Monthly
Preston and District Astronomical Society	35 Bispham Road, Carleton, Poulton-le-Fylde, Lancs (C. Lynch)	20*s* (§5*s*)	Chamber of Commerce, 49a Fishergate, Preston 3rd Mon. each month, Sept.–May
Salisbury Plain Astronomical Society	St George's Cottage Orcheston Salisbury, Wilts. (R. J. D. Nias)	10*s* (§5*s*)	St George's Rectory, Orcheston Quarterly
Sidereal Society	Flat 2, 11 Wellington Road, Brighton, Sussex (Mrs M. L. Cohen)	20*s* (§10*s*)	6 Brunswick Terrace, Hove, Sussex Each Wed., 7.30–9.30
Slough Astronomical Society	The Elms, Odds Farm, Green Common Lane, Wooburn Common, High Wycombe, Bucks (E. Shilton)	20*s*	Monthly
Southampton Astronomical Society	13 Luccombe Place, Shirley, Southampton (F. G. H. Cunningham)	20*s* (§10*s*)	Polygon Hotel, Southampton 2nd Thur. each month Sept.–May
Stoke-on-Trent Astronomical Society	19 Engelsea Avenue, Weston Coyney, Stoke (T. F. Stringer)	20*s*	Henley, near Stoke-on-Trent Monthly
Swansea Astronomical Society	77 Craiglwyd Road, Cockett, Swansea (R. E. Roberts)	20*s*	As arranged
Torbay Astronomical Society	4 Heath Rise, Brixham, Devon (Miss A. Longman)	15*s* (§5*s*)	Quay Tor Hotel, Scarborough Road, Torquay Monthly
Waltham Forest and District Junior Astronomy Club	24 Fulbourne Road, Walthamstow, London E17 (B. Crawford)	10*s*	24 Fulbourne Road, Walthamstow, London E17 Fortnightly (Mondays)
Warrington Astronomical Society	2 Dale Avenue, Appleton, Warrington (B. P. Rees)	20*s*	Central Library, Museum Street, Warrington, Lancs Monthly, Sept.–May

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Warwickshire Astronomical Society	20 Humber Road, Coventry, Warwickshire (R. D. Wood)	80*s*	20 Humber Road, Coventry Each Tuesday
Wolverhampton Astronomical Society	Garwick, 8 Holme Mill, Fordhouses, Wolverhampton (M. Astley)	20*s*	38 Tettenhall Road, Wolverhampton Alternate Mon., Sept.–April
Wyvern Astronomical Society	2 Howcroft, Churchdown, Gloucester (A. F. Edwards)	15*s* (§5*s*)	Clubhouse, Churcham Last Friday of each month except Aug.
York Astronomical Society	97 Carr Lane, Acomb, York (R. Emmerson)	20*s* (§5*s*)	As arranged Monthly, Sept.–May
Thanet Astronnmical Society for Youth	Woodlands, Fair Street, Broadstairs, Kent (Paul Sutherland)		In Process of organization

It is possible that this list of local societies may not be quite complete. If any have been omitted, the secretaries concerned are invited to write to the Editor (c/o Messrs. Sidgwick & Jackson (Publishers), Ltd, 1 Tavistock Chambers, Bloomsbury Way, London WC1), so that the relevant notes may be included in the 1970 *Yearbook*.

Yearbook of Astronomy 1969

Editor

PATRICK MOORE

The *Yearbook of Astronomy* has now been published regularly since 1962, and has become a standard reference book, used both by amateur and by professional astronomers.

This new edition follows closely upon the pattern of previous years. The notes and data for 1969 have been adapted as before; the star charts are valid for the whole year, and there are the usual details about forthcoming phenomena. The article section covers a wide range of topics, ranging from equipment to the Solar System, the stellar universe and beyond; it is hoped that there will, as always, be 'something for everybody', be he a beginner or a serious and skilled observer. The section for stellar enthusiasts contains a long article on the sky as seen through binoculars, together with lists of telescopic objects such as double stars, variables, clusters and nebulae. The list of astronomical societies has been brought up to date, and there are notes on recently-published books.

The new *Yearbook* will find its way into all astronomical libraries, and by now there are many observers who find it indispensable.

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The front cover illustration is of a portion of the Moon's surface, taken by Commander H. R. Hatfield with the 12-in. reflector at his private observatory at Sevenoaks, in Kent.

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